UK NATIONAL ARCHIVES CAT.: HO 225/96

CD12153

A12/CD/SA96

~~RESTRICTED~~

CD/SA 96

Reviewed April 1958

Declassified J.C.

Home Office
Scientific Advisers' Branch

The Decontamination of Residential Areas

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Effect of Type of Fall-Out

24. The type of fall-out will affect the effort needed to decontaminate access routes in a residential area. The fall-out may be typical of:

(a) a landburst in which the radioactivity is firmly fixed in the fall-out particles and there is no significant transfer of activity to the surface on which the fall-out is deposited even if the deposit is wetted by rainfall or is hosed or flushed away from the surface.

(b) an offshore and relatively deepwater burst in which large quantities of water and mud are lifted into the cloud so that the fall-out consists primarily of water droplets containing the radioactive fission products (or induced activity) in solution in colloidal suspension which can be transferred to the surface and be retained so tenaciously that the cost and effort of decontamination may be prohibitive.

25. Liquid droplet or "ionic" fall-out from an offshore waterburst would be much more localised and the radioactivity more intense than that from a landburst, leaving a much smaller fringe area in which decontamination might be of value compared with other remedial measures. It is the considered opinion of the Scientific Advisers' Branch that bursts of megaton weapons on British rivers such as the Clyde or the Thames would not raise enough water to produce fall-out differing significantly from that caused by a landburst and that water droplet fall-out with transferable activity would be infrequent compared with the landburst type of fall-out.

26. In view of the above considerations, the process of decontaminating a typical residential area will be primarily one of mechanical removal of the fall-out particles from the surfaces on which they have been deposited. They may be sucked or swept up into a container and removed to a safe dumping ground or they may be swept into the gutter and washed down into street drains or sumps. On some surfaces it may prove more effective to remove the bulk of the fall-out by dry sweeping or suction methods followed by flushing or fire hosing the surface to remove the remainder of the fall-out.

Surface Loading of Fall-Out Simulant in Area Decontamination Trials

30. Most of the trials with megaton weapons have taken place on coral islands and there is little reliable information on the relationship between the surface deposit of fall-out and the associated reference dose-rate contours, and none at all for megaton landbursts on clay or silicate soil. In one Pacific test the surface fall-out loadings at 8 miles and 60 miles downwind of ground zero of a 5 M.T. burst were estimated respectively at 4.5 and 0.06 gms. per square foot, but no systematic data are available.

Source: WT-1317
(Redwing-Tewa ships YFNB29 and LST611, 1 hr references: 200 and 6 R/hr)

31. In the large scale decontamination trials at Camp Stoneman in California in September, 1956, carriers impregnated with La 140 were used at a surface loading of 25 mgm. per square foot per r.p.h. at H + 1 hours, to simulate fall-out at 1000 to 10,000 r.p.h. at H + 1. It is probably easier to remove fall-out mechanically at the higher surface loadings and it is felt that the above figure is grossly excessive.

Appendix A (I)

Data extracted from Radiological Recovery of Fixed Military Installations

(Report TM 3-225, rev. Apr. 1958.) F.M.I. Sheet I

Performance of Common reclamation methods for paved areas and buildings

Surface of building or paved area	Standard dose-rate at 1 hour after burst	Residual Numbers for decontamination methods (1)		
		Firehosing or street flushing	Firehosing plus scrubbing	Hot liquid cleaning (2)
Asphaltic Concrete	300 1000 3000	0.07 0.03 0.01	0.05 0.02 0.008	0.02 0.01 0.004
Portland Cement Concrete	300 1000 3000	0.04 0.02 0.008	0.03 0.02 0.006	0.02 0.008 0.003
Tar and gravel roof	300 1000 3000	0.03 0.02 0.01	0.03 0.02 0.01	0.01 0.009 0.004
Composition roofing	300 1000 3000	0.04 0.03 0.01	0.04 0.02 0.01	0.02 0.01 0.005
Wood shingles (tiles)	300 1000 3000	0.17 0.10 0.04	0.13 0.08 0.03	0.06 0.04 0.01
Galvanised steel, corregated	300 1000 3000	0.05 0.02 0.006	0.04 0.01 0.005	0.02 0.006 0.002
Smooth painted surface	300 1000 3000	0.04 0.01 0.004	0.03 0.008 0.003	0.01 0.004 0.001

1. In this report the Residual Number is the fractional dose reduction in the centre of the area after the decontamination of the area plus a surrounding buffer zone of 600 feet width of paved or 200 feet of unpaved. Hence the Residual Number also represents the fraction of the radioactive contamination remaining on the surface.

2. Wet steam 105 psig 320°F (1500 lb/hr) and 1000 gal /hour water at 20 psig.

Appendix A(I)

F.M.I. Sheet 2 (Report TM 3-225, rev. Apr. 1958.)

Notes on procedure and rates of operation

Paved areas and structures

1. Firehosing

The data relate to the clean up of a large area, the fall-out being pushed into a drainage channel at the far edges. The data on rates of operation are much less than would be the case for typical British streets with gutters and drains.

Equipment: Hydrant, booster pump, $2\frac{1}{2}$ inch hose, Y branch feeding two $1\frac{1}{2}$ inch hoses each delivering 100 gallons per minute at 80 p.s.i.g.

Operators: Four men per $1\frac{1}{2}$ inch hose.

Rate: Areas 7,500 sq. ft. per hour per nozzle.
Structures 2,000 sq. ft. per hour per nozzle.

2. Motorised flushing (for large areas only)

Equipment: Flusher delivering 800 gallons per minute at 90 p.s.i.g.

Operators: Two men.

Rate: 35,000 sq. ft. per hour.

3. Hot liquid cleaning

Equipment: Injector Unit, lance and nozzle, steam (1500 lb/hour unit at 105 p.s.i.g. and 320°F): Water (1000 gallons per hour at 20 p.s.i.g.) and Detergent.

Operators: Three men per lance.

Rate: Roofs 2500 sq. ft./hour
Walls 2000 sq. ft/hour.

Appendix A(i)

(Report TM 3-225, rev. Apr. 1958.) F.M.I. Sheet 3

Reclamation characteristics of various surfaces

Surface	Reclamation Characteristics
Composition shingles Prepared roll roofing Tar Paper	Similar to composition roofing
Corrugated sheet metal Steel Transite Glazed brick or tile Tin Copper	Similar to galvanised steel, corrugated
Unpainted wood Wood piles, piers and posts Gypsum or fibreboard Unglazed tile or brick	Similar to wood shingles (i.e. wooden tiles)
Dense brick Cinder or concrete block Adobe brick Semi-glazed roof tile Stone	Similar to Portland Cement, concrete
Slate Asbestos shingles or siding Concrete piles, piers or posts Stucco	Similar to Portland Cement, concrete

Appendix A(i)

F.M.I. Sheet 4 *(Report TM 3-225, rev. Apr. 1958.)*

Performance of Common reclamation methods for unpaved land areas

Method	Residual Number (1) for single pass
Ploughing (8 to 10 inches depth)	0.15
Motor Grader scraping (2) (2 to 4 inches cut)	0.07
Motorised scraping (3) (2 to 6 inches cut)	0.15
Filling (to 6 inches depth)	0.15
Motorised scraping plus either ploughing or filling	0.02

(1) See note Sheet 1.

(2) Earth pushed by slanting blade into windrows which are removed from the site.

(3) Earth lifted into a bucket and dumped off site - higher R.N. due largely to spillage.

Appendix A(i)

F.M.I. Sheet 5 (Report TM 3-225, rev. Apr. 1958.)

Unpaved Land

1. Ploughing

Three share plough drawn by 125 HP tractor

Rate 35,000 sq. ft. /hour

One operator per gang of ploughs.

2. Motor grader scraping (without time for removal of windrows)

Motor grader with 10 ft. blade.

Rate along a 16 ft. wide roadway one pass on each half of road.

4,000 linear ft. /hour or

64,000 square ft. /hour.

3. Motorised scraper and bulldozer

The scraper takes soil into a bucket and the rate depends on the distance to the dumping ground and on the roughness of the ground.

4. Filling to a depth of 6 inches

Motorised scraper and bulldozer or mechanical shovel and truck.

Rate 3,000 to 10,000 sq. ft. depending on length of haul and nature of soil.

Appendix A(i)

F.M.I. Sheet 6 (Report TM 3-225, rev. Apr. 1958.)

LOGISTICS of Decontamination

Method	Equipment Required per 100,000 sq. ft.(1)	Manpower requirements per unit of equipment
Firehosing Areas	0.28 hoses	4 men
Firehosing structures	1.04 hoses	2 men
Motorised street flusher	0.06 flushers	2 men
Firehosing and hand scrubbing on paved areas	0.42 hoses 0.84 brushes detergents	4 men per hose 2 men for scrubbing
Firehosing and scrubbing on structures	1.04 hoses 2.08 brushes 2.08 shovels detergents	4 men per hose 2 men for scrubbing
Hot liquid cleaning of roofs	0.84 lances	4 men
Ploughing	0.06 tractor with plough	1 man
Motor grader scraping	0.033 motor graders	1 man
Motorised scraping	0.42 scrapers	1 man
Filling	0.42 scrapers	1 man
Bulldozing	0.25 dozers	1 man

(1) Based on 48 hours operation of equipment: numbers are also based on 100% efficiency and do not allow time for setup or rest periods. These factors may reduce the efficiency by 15 to 25%.

SYSTEMS ANALYSIS OF RADIOLOGICAL DEFENSE. Kendall D. Moll. Nov. 1958. 124p. (NP-7241) Stanford Res. Inst.

Appendix A(ii)

S.R.I. Sheet 1

Performance Value of Decontamination Measures

(Assuming crew exposure factor of 0.5 i.e. P.F. = 2)

(Data in U.S. gals. = 0.83 British gals.)

Decontamination Measure	Supply needs (per 1000 sq.ft.)	Rate of Coverage sq.ft/man-hr.	Fraction of Radiation Removed	Performance Value (see script)
Roofs				
Firehosing	0.4 gal gas 200 water	1,000	0.9	1,800
Firehosing and scrubbing	0.7 gal gas 1500 water	300	0.93	560
Firehosing and detergent scrubbing	same plus 2 lb detergent	300	0.97	580
Vacuum cleaning	Electricity	-	0.80	-
Paved Areas				
Firehosing	0.15 gal gas 700 water	2,000	0.96	3,800
Firehosing and scrub	0.2 " " 700 water	900	0.97	1,700
Firehosing and detergent scrub	same plus 2 lb detergent	900	0.98	1,800
Motorised flushing	0.3 gal gas 500 water	15,000	0.98	73,000
Motorised sweeping	0.1 gal gas	25,000	0.90	110,000
Unpaved Areas				
Power scraping or bull-dozing	0.5 gal gas	5,000	0.85	21,000
Motor grading	0.2 gal gas	25,000	0.85	110,000
Gang ploughing	0.2 gal gas	20,000	0.85	85,000
Spading (hand)		50	0.85	85
Obstructions (trees, fences etc.)				
Firehosing	0.4 gal gas 2000 water	1,000	0.8	1,600
Firehosing and scrubbing	0.7 gal gas 2500 water	300	0.9	540
Outside Walls				
Firehosing	0.3 gal gas 1300 water	1,500	0.97	2,900
Firehosing and scrub	0.4 gal gas 900 water	500	0.98	980
Firehosing and detergent scrub	same plus 4 lb detergent	500	0.99	990
Vacuum cleaning	Electricity	-	0.97	-

SYSTEMS ANALYSIS OF RADIOLOGICAL DEFENSE. Kendall D. Moll. Nov. 1958. 124p. (NP-7241) Stanford Res. Inst.

Appendix A(ii)

S.R.I. Sheet 2

Distribution of surface area types in a typical American City and their radiation contributions inside shelters

Type of Surface	Shelter in			
	Dwelling houses PF = 2		Commercial Areas Large buildings PF = 10	
	Surface Area sq. ft. per capita	Fraction of the total external radiation penetrating into the shelter from the specified surfaces	Surface Area sq. ft. per capita	Fraction of the total external radiation penetrating into the shelter from the specified surfaces
Roofs	300	0.15	150	0.060
Streets	350	0.06	150	0.005
Other paved areas	300	0.10	150	0.010
Unpaved areas	1,000	0.15	300	0.014
Obstructions (fences, trees, etc.)	400	0.02	100	0.001
Outside Walls	400	0.02	200	0.010
Total exposure as fraction of external		0.50		0.100

SYSTEMS ANALYSIS OF RADIOLOGICAL DEFENSE. Kendall D. Moll. Nov. 1958. 124p. (NP-7241) *Stanford Res. Inst.*

Appendix A(ii)

S.R.I. Sheet 3

Decontamination Values for dwelling houses (residential areas) and large buildings (commercial areas). Crew exposure factor 0.5 (i.e. P.F.= 2)

Decontamination Measure	Decontamination Value		Hours work per capita to decontaminate		Fraction of radiation removed from the surface	Supply needs per capita to decontaminate all City areas (U.S. gals = 0.83 British gals.
	Houses (residential)	Large Buildings (commercial)	Houses (residential)	Large Buildings (commercial)		
Roofs 300 sq. ft. residential 1500 sq. ft. commercial						
Firehosing	0.90	0.72	0.30	0.15	0.90	0.2 gals gas 900 gal water
Firehosing and detergent scrubbing	029	0.23	1.0	0.5	0.97	0.3 gals gas 700 gal water 3lb detergent
Streets 350 sq. ft. residential 150 sq. ft. commercial						
Firehosing	0.65	0.11	0.18	0.08	0.96	0.08 gal gas 350 gal water
Motorised flushing	12.0	2.2	0.023	0.01	0.98	0.15 " " 250 " "
Motorised sweeping	19.0	3.1	0.014	0.006	0.90	0.05 " "
Other paved areas 300 sq. ft. residential 150 sq. ft commercial						
Firehosing	1.1	0.27	0.15	0.08	0.96	0.07 gal gas 300 gal water
Unpaved areas 1000 sq. ft. residential 300 sq ft. commercial						
Power scraping or bulldozing	3.6	1.0	0.2	0.06	0.85	0.7 gal gas
Motor grading	16.0	5.5	0.04	0.01	0.85	0.3 " "
Gang ploughing	13.0	4.2	0.05	0.015	0.85	0.3 " "
Spading (by hand)	0.013	0.004	20.0	6.0	0.85	-
Obstructions 400 sq. ft. residential 100 sq. ft. commercial						
Firehosing	0.080	0.016	0.4	0.1	0.80	0.2 gal gas 1000 gal water
Firehosing and scrubbing	0.027	0.005	1.3	0.3	0.90	0.4 " " 1300 " "
Outside Walls 400 sq. ft. residential 200 sq. ft. commercial						
Firehosing	0.15	0.15	0.27	0.13	0.17	0.2 gal gas 800 gal water
Firehosing and detergent scrubbing	0.05	0.05	0.8	0.4	0.99	0.2 " " 600 " " 2lb detergent

Appendix B(i)

U. S. Studies on the decontamination of representative roofing materials
(Reports CRLR 307 and 308)

Panels, 4 ft. x 4 ft. sloped at an angle of 15 degrees except for the built-up tar and gravel roofs which had a slope of 2 degrees, were each contaminated with 210 mgs of a "dust" of Tantalum 182 irradiated to about 5 mc/gm. (Half life 117 days, 1.22 Mev gamma, particle size distribution not available).

The general conclusions were that if water hosing is used at least 40 psig is needed to achieve 90% removal of the contamination.

Vacuum cleaning was also very effective on rough surfaces but it took about three times as long as high pressure hosing.

On smooth surfaces weathering (a 5 to 7 m.p.h. wind) removed 60% of the activity in one day and the wind and rain removed 90% in forty-seven days. Rough surfaces showed 30 to 40% removal of activity by weathering after seven weeks.

The results are shown in R. P. Sheet I and it is to be noted that the roofing materials used are in no way typical of British materials.

Decontamination of Radioactive Ta - 182 dust from various roofing materials.

Reports CRLR 307 and 308 (July/August 1953)

Appendix B(i)

R. P. Sheet I (Roof Panels)

Decontamination Method	Surface Material	Total Time Minutes unless stated	Total water gallons	% Decontamination
Low pressure hosing 8 psig	Rolled asphalt	2	10	98
	strip shingle	4	20	84
	corrugated metal	2	10	95
	built-up tar and gravel	4	20	23
Low pressure hosing and brushing	r. a.	2	10	96
	s. s.	3	15	88
	c. m.	1	5	98
	t. and g.	4	20	44
Hosing 24 psig	t. and g.	45 sce.	6.5	32
Firehosing 40 psig	t. and g.	60 sec.	12.5	98
High pressure hosing 50 psig	r. a.	15 sec.	3.5	88
	s. s.	30 sec.	7.0	96
	c. m.	15 sec.	3.5	100
	t. and g.	60 sec.	14	95
H. P. hot water and steam (Seller's Unit) 90 psig hot water 8.3 gpm.	r. a.	30 sec.	4.2	94
	s. s.	1 min.	8.4	69
	c. m.	30 sec.	4.2	97
	t. and g.	1 min.	8.4	91
Vacuum cleaning	r. a.	2.5		99
	s. s.	2.5		91
	c. m.	1.5		97
	t. and g.	2.5		98
Dry sweeping	r. a.	2		82
	s. s.	2		0.9
	c. m.	2		96
	t. and g.	2		12

Decontamination of Radioactive Ta - 182 dust from various roofing materials.

Reports CRLR 307 and 308 (July/August 1953)

Appendix B(ii)

Plumb Bob Trial on Unpaved Ground

In this trial an area about 1 mile from ground zero of a tower burst bomb was contaminated to a peak intensity of about 60 r.p.h. A square 500 ft. by 500 ft. was monitored by recorders who came out of a nearby underground shelter and it was decontaminated starting at about H + 48 hours by a team of men with equipment brought from outside the contaminated area. It was again monitored after decontamination.

The ground consisted of stony desert from which boulders and larger stones had been scraped before the trial. It therefore represented the most difficult type of unpaved surface to clean by earth moving techniques.

Equipment used

- 4 motor graders (2 inch cut)
- 2 motorised scrapers
- 1 bulldozer

Procedure A 40' x 40' square was first cleared by the motor graders: this was enlarged to 60' x 60' by a 10' pass all round (pushing windrows to the periphery) and finally extended to 100' x 100'. Several trips with the scrapers were necessary to remove the windrows.

Finally a 200' wide buffer zone was cleared around the 100' x 100' area making a total cleared area of 500' x 500'.

Another 100' x 100' area was cleared in the same way but a 3' high earth barrier was built up round its periphery instead of the buffer zone.

The results of the decontamination are shown below in terms of the percentage residual dose-rate at the centre of the square.

Area cleared	Average % residual dose-rate at centre of the cleared square
40' x 40'	39
60' x 60'	32
100' x 100'	24
500' x 500'	16
After second pass over central 100' x 100' area	11
Centre of 100' x 100' Area with 3 ft. high earth barrier around it.	16

/Duration

U.S.A.E.C. Report ITR 1464 (14/2/58)

Operation Plumbbob (Nevada, summer 1957)

Evaluation of Countermeasures System Components and Operational Procedures (CD 11605)

Duration of task of clearing 500' x 500' area - 3 hours

Average Protective Factor of operators of the equipment - 5

(from doses recorded on their film badges.)

U.S.A.E.C. Report ITR 1464 (14/2/58)

Operation Plumbbob (Nevada, summer 1957)

Evaluation of Countermeasures System Components and Operational Procedures (CD 11605)

Appendix B(iii)

Camp Stoneman Trials September 1956

The large deserted Military Camp Stoneman was used for this trial Large areas of paved ground with different types of surface and huts with different types of roofing material were contaminated to an extent which was estimated to correspond to 1000 and 10,000 r.p.h. at H + 1 hours.

For this purpose a surface loading of fall-out simulant of 25 mg per sq. ft. per 1 r.p.h. at H + 1 i.e. 25 gms/sq. ft. to represent 100 r.p.h. and 250 gms/sq.ft. to represent 10,000 r.p.h. at H + 1 were chosen. It was later considered that this was much too heavy a contamination and the results were interpolated to 3000 r.p.h. at H + 1 but it was felt that they could not be extrapolated down to 300 r.p.h. at H + 1 without serious misgivings.

Two types of fall-out simulant were used, a dry powder and a slurry but both were in fact typical only of a landburst weapon as there was no transfer of radioactivity from the carrier particles into the solution or on to the surface contaminated.

The fall-out simulants were based on a solution of Lanthanum - 140 (half life 40.2 hours, 1.2 Mev gamma emission) which was mixed with the appropriate carrier material. The powdered simulant consisted of Camp Stoneman loam soil (40,000 lb used) impregnated with the La 140 solution: The slurry (30,000 lbs) was produced by impregnating dried harbour mud from San Francisco bay with the La - 140 solution and then adding an equal weight of water.

The results of various decontamination procedures on different types of surface in terms of effectiveness, rate of operation and man-hours effort are shown in Tables 5.1 to 5.6 reproduced from Report U.S. NRDL - TR- 196. The planning rates and effort include time required to set up the equipment and to move it from area to area and also include an adjustment for an estimated 75% efficiency in the productive effort.

Table 5.7 is also included: it contains data estimated on a similar basis for transferable or ionic fall-out from an off-shore water burst. The data in Table 5.7 have been estimated from laboratory experiments and some very limited data from two water burst trials.

U.S. NRDL - TR - 196 (27.12.57)

Cost and Effectiveness of Decontamination Procedures for Land Targets (Test at Camp Stoneman, California, September 1956) (CD 12030)

Appendix B(iii)

Camp - Stoneman Trials

Table 5.1 Expected Recovery Performance on Asphaltic Concrete Exposed to Dry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effec-tiveness[b]	Plann'g Rate	No. of men	Effort[c]	Resid'l Std. Dose Rate	Effec-tiveness[b]	Plann'g Rate	No. of Men	Effort[c]
PROCEDURE	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$
Column	1	2	3	4	5	1	2	3	4	5
Motorized Flushing	8-16	.01	35	2	0.06	18-32	.006-.01	35	2	0.06
Firehosing	1-100[d]	.04	15	6-8	0.4-0.5	16-94[d]	.02	15	6-8	0.4-0.5
FH-HSD-FH[a]	12-19	.01-.02	10	11-13	1.1-1.3	26-38	.01	10	11-13	1.1-1.3

Table 5.2 Expected Recovery Performance on Portland Cement Concrete Exposed to Dry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
	Resid'l Std. Dose Rate	Effec-tiveness[b]	Plann'g Rate	No. of Men	Effort[c]	Resid'l Std. Dose Rate	Effec-tiveness[b]	Plann'g Rate	No. of Men	Effort[c]
PROCEDURE	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$	r/hr	Residual Number	$\frac{1000\ ft^2}{hr}$		$\frac{Man\ hrs}{1000\ ft^2}$
Column	1	2	3	4	5	1	2	3	4	5
Motorized Flushing	6-12[e]	.01	35	2	0.06	8-27	.003-.009	35	2	0.06
Firehosing	19-34	.02-.03	15	6-8	0.4-0.5	18-35	.006-.01	15	6-8	0.4-0.5
FH-HSD-FH[a]	6-11	.01	10	11-13	1.1-1.3	9-14	.003-.005	10	11-13	1.1-1.3

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of residual standard dose rate/initial standard dose rate:

[c] Effort, in man hr/1000 ft^2, results from dividing the number of men involved by the planning rate: $\frac{\text{column } 4}{\text{column } 3}$

[illegible] Poor specific activity data provided an extremely large confidence interval.

[e] This data from MF-MS-MF test results, and it is assumed that the MS operation did not add to the decontamination effectiveness.

Appendix B(iii)

Camp - Stoneman Trials

Table 5.3 Expected Recovery Performance on Asphaltic Concrete Exposed to Slurry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
PROCEDURE	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft²/hr	No. of Men	Effort[c] Man hrs/1000 ft²	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft²/hr	No. of Men	Effort[c] Man hrs/1000 ft²
Motorized Flushing	44-58	.05	28	2	0.07	47-57	.02	28	2	0.07
Firehosing	24-70	.03-.07	9	6-8	0.7-0.9	50-74	.02	9	6-8	0.7-0.9
FH-HSD-FH[a]	34-41	.04	9	11-13	1.2-1.4	36-42	.01	9	11-13	1.2-1.4

Table 5.4 Expected Recovery Performance on Portland Cement Concrete Exposed to Slurry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
PROCEDURE	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft²/hr	No. of Men	Effort[c] Man hrs/1000 ft²	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft²/hr	No. of Men	Effort[c] Man hrs/1000 ft²
Motorized Flushing	35-52	.04	28	2	0.07	43-56	.01-.02	28	2	0.07
Firehosing	36-55	.04	9	6-8	0.7-0.9	36-55[e]	.01-.02	9	6-8	0.7-0.9
FH-HSD-FH[a]	8-62[d]	.01-.06	9	11-13	1.2-1.4	8-62[e]	.003-.02	9	11-13	1.2-1.4

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of residual standard dose rate/initial standard dose rate:

[c] Effort, in man hr/1000 ft², results from dividing the number of men involved by the planning rate: $\frac{\text{column 4}}{\text{column 3}}$

[d] Inconsistent results provided the wide range.

[e] The r[illegible]ge was expanded and adjusted to equal the width and magnitude of the 1000 r/hr values.

Appendix B(iii)

Camp Stoneman Trial

Table 5.5 Expected Recovery Performance on Roofs Exposed to Dry Contaminant

	1000 r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
SURFACE and PROCEDURE	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Planning Rate 1000 ft2/hr	No. of Men	Effort[c] Man hrs/1000 ft2	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Planning Rate 1000 ft2/hr	No. of Men	Effort[c] Man hrs/1000 ft2
Column	1	2	3	4	5	1	2	3	4	5
Corrugated Metal										
Firehosing	29	.03	3.9	2	0.5	30	.01	3.9	2	0.5
FH-HSD-FH[a]	5	.005	4.8	5	1.0	12	.004	3.9	5	1.3
Tar and Gravel										
Firehosing	38	.04	1.5	4	2.7	38	.015	1.5	4	2.7
FH-HSD-FH[a]	10	.01	1.8	7	3.9	31	.01	1.8	7	3.9
Roll Roofing										
Firehosing	54	.05	3.0	2	0.7	54	.02	3.0	2	0.7
FH-HS-FH	15	.015	3.9	5	1.3	30	.01	3.3	5	1.5
Composition Shingle										
Firehosing	60	.06	3.0	2	0.7	70	.02	3.0	2	0.7
FH-HS-FH	31	.03	3.0	5	1.7	46	.015	2.7	5	1.8
Wood Shingle										
Firehosing	100	.10	2.1	2	1.0	200	.07	2.1	2	1.0
FH-HS-FH	50	.05	1.5	5	3.3	100	.03	1.5	5	3.3

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[illegible] Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/intial standard dose rate:

[illegible] Effort, in man hrs/1000 ft^2, results from dividing the number of men involved by the planning rate: column 4/column 3.

Appendix B (iii)

Camp - Stoneman Trials

Table 5.6 Expected Recovery Performance on Roofs Exposed to Slurry Contaminant

	1000r/hr Initial Standard Dose Rate					3000 r/hr Initial Std Dose Rate				
Surface and Procedure	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft² / hr	No. of Men	Effort[c] Man Hrs / 1000 ft²	Resid'l Std. Dose Rate r/hr	Effectiveness[b] Residual Number	Plann'g Rate 1000 ft² / hr	No. of Men	Effort[c] Man hrs / 1000 ft²
Column	1	2	3	4	5	1	2	3	4	5
Corrugated Metal										
Firehosing	30	.030	2.7	2	0.7	38	.013	2.7	2	0.7
FH-HSD-FH[a]	7	.007	3.0	5	1.7	17	.006	2.7	5	1.8
Tar and Gravel										
Firehosing	55	.055	1.5	4	2.7	55	.018	1.5	4	2.7
FH-HSD-FH	45	.045	1.8	7	3.9	50	.017	1.8	7	3.9
Roll Roofing										
Firehosing	120	.12	1.8	2	1.1	120	.04	1.8	2	1.1
FH-HS-FH	55	.055	3.0	5	1.7	55	.018	2.7	5	1.8
Composition Shingle										
Firehosing	250	.25	1.8	2	1.1	250	.083	1.8	2	1.1
FH-HS-FH	170	.17	2.4	5	2.1	200	.067	2.4	5	2.1
Wood Shingle										
Firehosing	250	.25	1.5	2	1.3	250	.083	1.5	2	1.3
FH-HS-FH	170	.17	0.9	5	5.6	200	.067	0.9	5	5.6

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/initial standard dose rate.

[c] Effort, in man hrs/100 ft², results from dividing the number of men involved by the planning rate: column 4/column 3.

Appendix B(iii)

Miscellaneous Laboratory and Weapon Trials data on Offshore Waterburst fall-out (activity transferable)

Table 5.7 Expected Recovery Performance on Paved Areas and on Roofs Exposed to Wet (ionic) Contaminant

Surface	Procedure	Range of[b] Effectiveness (Residual Number)	Planning Rate ($1000\ ft^2$/hr)	No. of Men	Range of Effort[c] (Man hrs/1000 ft^2)
Pavements Concrete or Asphalt	Motorized Flush'g	.50 - .75	27	2	.07
	Firehosing	.55 - .85	9	6 - 8	0.7 - 0.9
	FH-HSD-FH[a]	.35 - .55	9	11 - 13	1.2 - 1.4
	Heater Planer[d]	.04 - .06	4 - 8	3 - 4	.4 - 1.0
Roofs					
Tar and Gravel	Firehosing	.20 - .30	1.5	4	2.7
	FH-HSD-FH[a]	.05 - .15	1.8	7	3.9
Roll Roofing	Firehosing	.65 - .85	3.0	2	0.7
	FH-HS-FH	.20 - .50	2.4	5	2.1
Comp. Shingles	Firehosing	.65 - .85	3.0	2	0.7
	FH-HS-FH	.25 - .55	2.4	5	2.1
Corrg. Metal	Firehosing	.60 - .90	2.4	2	0.8
	FH-HS-FH	.40 - .55	1.8	5	2.8
Wood Shingles	Firehosing	.75 - .85	2.4	2	0.8
	FH-HS-FH	.35 - .75	1.8	5	2.8

[a] Firehosing plus handscrubbing with detergent followed by a second firehosing.

[b] Residual number, as a measure of effectiveness, is the ratio of the residual standard dose rate/initial standard dose rate.

[c] Effort, in man hours/1000 ft^2, results from dividing the number of men involved by the planning rate.

[d] Restricted to surface removal of asphalt paving only. Greater rate based on use of skip loader for truck with debris. Lesser rate relies on 2 laborers to shovel debris into truck. The results of this destructive decontamination method shows that surface removal techniques are required to achieve low residual numbers.

U.S. NRDL - TR - 196 (27.12.57)

Cost and Effectiveness of Decontamination Procedures for Land Targets (Test at Camp Stoneman, California, September 1956) (CD 12030)

Records.

CD/SA 96
Addendum

Home Office
Scientific Adviser's Branch

The Decontamination of Residential Areas

Application of U.S. performance data to a London District

J. McAulay

Introduction

1. American data on the decontamination of large areas are reviewed in Paper CD/SA 96. The object of the present supplement is twofold:

(i) To describe a method and chart for quick assessment of the equipment, manpower and time needed to decontaminate the pavements and streets in any built-up area under the wide range of conditions likely to be encountered in nuclear warfare and

(ii) To apply the chart and the U.S. experimental data to the decontamination of a typical heavily populated residential area about 7 miles south of the centre of London.

2. CD/SA 96 also mentioned British plans for public control in a contaminated area to avoid radiation sickness and possible death. These plans assume an initial period of up to 48 hours in a radiological refuge: for the following week or two, when possible, the daily periods of exposure out-of-doors to perform essential services or to get necessities for the family, should be limited to 2 hours in the more heavily contaminated and 4 hours in the less heavily contaminated zones. It is also shown that about two thirds of the total dose accumulated by people who will have to remain in the contaminated zones will be acquired during these short outdoor periods. The decontamination of access routes from houses to the local distribution centres in built-up areas therefore offers a possibility of reducing the subsequent dose to the population by a factor of two or more and of permitting an earlier resumption of normal community life and activities.

3. The effort required to decontaminate a built-up area will depend not only on the local intensity of radiation at the time but also on the water supplies and on the type and amount of equipment, particularly of mechanised equipment, available. In most European towns equipment will be the limiting factor which will determine when the work can be started, how long it will take and how many men will be needed within the restriction that none of them should get more than a limited and agreed dose of gamma radiation.

4. The inner commercial centres of towns, where the resident population is small, frequently have pavements wide enough to permit the passage of mechanised street cleaning equipment in spite of obstructions such as poles, lampposts, post boxes etc. near the pavement edge. In many residential districts the pavement width may be 7 ft. or less so that mechanised equipment might have to be confined to the street: in such cases a small contribution from the residents would be required to brush or wash contamination from the sidewalks and the pavement in front of each house into the street gutter.

5. Major limiting factors are the starting time t, and the working shift length i.e. the number of hours $\triangle T = t_1 - t_2$ that men can work in a contaminated area before they get the allowed dose of radiation D_a. It is assumed that the gamma dose-rate will decay as a function of $t^{-1.2}$ during the first few weeks, after the nuclear detonation. If R_1 is the one hour reference dose-rate and if f? the factor of protection afforded by any vehicle used for decontamination, then the dose D_a which may be incurred from t_1 to t_2 hours is

$$D_a = \frac{5\ R_1}{f} \left\{ t_1^{-0.2} - t_2^{-0.2} \right\}$$

In the more heavily contaminated areas D_a may be accumulated in a single short work shift but in less heavily contaminated areas it will be possible for individuals to do repeated shifts separated by 8 or 12 hour rest periods: the work will take longer but will require less equipment and fewer men.

The allowed dose D_a

6. In the U.K. a Wartime Emergency Dose (WED) limit of 75r (100r under exceptional circumstances) has been accepted for Civil Defence life-saving operations. A limit has not yet been officially specified for decontamination operations and in this paper the 75r limit has been assumed to be applicable to the decontamination of access routes to permit the restoration of the essential activities of the community. Clearly, therefore, if the maximum use is to be made of specially trained men, the decontamination personnel must be given the best possible radiological protection during the early period of high dose-rate and rapid decay.

Transit dose

7. Decontamination crews will presumably operate from radiological shelters within the same district and they will not have to travel more than a few miles in an automobile at a speed of at least 30 m.p.h. Transit doses will therefore be negligible compared with the allowed dose D_a except in very heavily contaminated areas or where distances are more than 2-3 miles when the transit dose D_{trans} will have to be deducted from D_a. It may be calculated with sufficient accuracy for decontamination operations from the estimated transit time multiplied by the mean dose-rate over the distance to be travelled.

Starting time t, and duration of working shift $(t_1 - t_2)$

8. Assuming a mean protective factor "f" over the transit and working time

$$(D_a - D_{trans})\ f = 5R_1 \left\{ t_1^{-0.2} - t_2^{-0.2} \right\}$$

All variables other than time t can be grouped into one parameter

$$K = \left(\frac{D_a - D_{trans}}{5R_1} \right) f = \left(t_1^{-0.2} - t_2^{-0.2} \right)$$

In Fig. 1 the shift duration $\Delta T = t_1 - t_2$ has been plotted against the starting time t_1 for a family of curves covering a range of likely or useful values of K. Fig. 1 can be used to determine any one of the variables ΔT, t_1 and K (and hence also of D_a) given the other two.

Heavily populated residential area in London

9. Details of a residential area to the north of Croydon and 7 miles south of the centre of London are given in Table 1. It consists mainly of rows of two or three storey terraced houses in streets at right angles to a main shopping and business thoroughfare: the latter consists of three storey terraced buildings with residences frequent in the upper floors.

Table I

Normal population			about 16,000
Total area (about 160 hectares)			399 acres
Streets length			73,000 ft.
Pavement widths			7 ft.
Area streets and pavements (67 acres)			2.92×10^6 sq. ft.
Other details			
Open spaces other than house gardens			20.0 acres
Church buildings	(5)	plan area	0.67 "
School buildings	(3)	" "	0.58 "
Halls	(4)	" "	0.47 "
Public Library	(1)	" "	0.09 "
Pavilions and Club Houses	(4)	" "	0.24 "
Houses and shops	(4,453)	" "	63.70 "
Balance: back and front gardens of houses and courts of larger buildings			about 246 acres.

Decontamination techniques and types of equipment

10. The U.S. data related to the decontamination of a large paved area (airfield) from which the fall-out was pushed by mechanised road sweepers into windrows and carted away to a prepared dump or it was washed into drainage channels, round the periphery of the area by motorised flushing machines or hand operated fire hoses.

11. There is little reliable information on the likely density of fall-out deposits in relation to intensity of radiation. In this paper a range of 20 to 0.05 gms per sq. ft. is assumed (20 to 0.05 mg/cm^2). Thus over the pavements and streets of the London district under consideration, the amount of fall-out to be removed could range from 60 metric tons to a fraction of one ton.

12. British towns have a street drainage system which would greatly facilitate the disposal of all but the heaviest fall-out in sweeping it into the street gutters and then flushing or hosing it down into the drains. The U.S. rates of operation would be applicable to mechanised road sweepers with collector boxes and to motorised flushers, because of the time needed to empty the boxes or to fill the large water tanks. It is considered however that the U.S. rates for fire-hosing from a hydrant or pump and emergency reservoir would be too slow for British streets in which a road sweeper pushes the fall-out into the gutters and it is then hosed into the drains using the trailer pumps of the auxiliary fire service. (For very heavy fall-out the use of road sweepers with collector boxes would be preferable).

13. The performance data assumed in this paper for decontamination assessment are shown in Table 2.

Table 2

Equipment	Effectiveness % contamination removed	Number of crew per Unit	Rate of Operation sq. ft. per hour/unit	Assumed Protective Factor
A. Mechanised road sweeper U.S.	90	1	25,000	3
B. Motorised flusher (U.S.) 800 U.S. g.p.m. at 90 p.s.i.g.	98	2	30,000	2
C. Firehosing (U.S.) 100 g.p.m. at 80 p.s.i.g.	96	4 per nozzle	7,500	1.25 (see para 23)
D. U.K. Combined road sweeper and firehosing	96?	1 4 per nozzle	80,000 20,000	3 1.25

Application to a London District (Table 1)

(Area of streets and pavements 2.92×10^6 sq. ft)
Normal population 16,000

A. Mechanised road sweeper (U.S.) Crew 1. Da = 75r f = 3

14. If the job had to be completed in a single shift of 8 hours, fifteen machines and fifteen operators would be needed. If it could wait until decay permitted each man to do a repeat 8 hour shift after 12 hours rest then eight machines and eight men would be needed.

15. Estimated from the chart Fig. 1, the earliest starting times and the shift times for different one hour reference dose-rates are shown in Table 3.

Table 3

Mechanised road sweepers $f = 3$

R r.p.h.	K	Earliest shift hours	D_a r per man
Single 8 hour shift, 15 sweepers, 15 men			
10,000	.0045	H + 125 to H + 133	75
3,000	.015	H + 46 to H + 54	75
1,000	.045	H + 16 to H + 24	75
Two 8 hour shifts each for 8 men, 8 sweepers			
1,000	.030	H + 24 to H + 32	50)) 76
	.0157 (from Fig.1)	H + 44 to H + 52	26)
500	.060	H + 12 to H + 20	50)) 69
	.022 (from Fig.1)	H + 32 to H + 40	19)

16. If only a single machine were available and it was used continuously, the decontamination would take 117 hours. In an area of R_1 = 1000 r.p.h. and for D_a = 75 and f = 3, K = 0.045, it can be seen from Fig. 1 that if necessary a first 4 hour shift could start at H + 10 hours and decontamination could be completed by D + $5\frac{1}{4}$ days. A total of eight to nine men would be needed, working in 4 hour shifts with 12 hour rest periods between, each being replaced by another as he reached his limit of 75r. Even so, at least three of the nine men would get less than half the allowed dose with a balance of $1\frac{1}{2}$ "radiological lives" for other work.

17. It is clearly an advantage to use at least two mechanised sweepers and more where $R_1 \gg 1000$ r.p.h. since there is little difference between manpower needed to complete the work with eight machines during the third day and with one machine during the sixth day.

B. Motorised flusher (U.S.) Crew 2. D_a = 75r. f = 2

18. This technique is dependent on an ample supply of water. The water requirement is quoted as 500 U.S. gal. per 1000 sq. ft. so that for the total area of 2.92×10^6 sq. ft. of streets and pavements, 1.5×10^6 U.S. gal or 5700 m^3 of water would be needed (1 U.S. gal = 3.78 litres).

19. If the job had to be completed in a single working shift of 8 hours, 12 machines (24 men) would be needed. If it could wait until decay permitted each crew to work an additional shift (preferably in daylight) with a 12 hour rest period between, then the work could be done with 6 machines (24 men). The earliest starting times for different one hour reference dose rates have been estimated from Fig. 1 and are shown in Table 4.

Table 4

Motorised flusher f = 2

R_1 r.p.h.	K	Earliest shift hours	Da r/man
Single 4 or 8 hour shift for 24 men in 12 machines			
10,000	.0030	H + 185 to H + 189	75
3,000	.010	H + 65 to H + 73	75
1,000	.030	H + 24 to H + 32	75
Two 7 or 8 hour shifts each for 24 men in 6 machines			
1,000	.020 .012 (from Fig.1)	H + 35 to H + 43 H + 55 to H + 63	50) 80 30)
500	.040 .0184	H + 18 to H + 26 H + 38 to H + 46	50) 73 23)

20. If only one motorised flusher were available and it was used continuously, decontamination of the 2.92×10^6 sq. ft. of streets and pavement would take about 98 hours. In an area where R_1 = 1000 r.p.h. and for Da = 75 and f = 2, K = 0.030 it can be seen from Fig. 1 that a first 4 hour shift could start at H + 13 hours. A rough estimate can be made from Fig. 1 that not more than 20 men would be needed to decontaminate the whole area by about D + $4\frac{3}{4}$ days.

C. Firehosing by hand (U.S.)

21. This technique of decontamination would have to be used where no equipment other than that of the fire service was available. The U.S. data are based on the use of $1\frac{1}{2}$ inch hoses fitted with $\frac{5}{8}$ inch nozzles, delivering 100 U.S. gals. per minute at 80 p.s.i.g, with an overall manpower requirement of 4 men per nozzle and a cleaning rate of 7,500 sq. ft. per nozzle per hour.

22. The total water requirement would be about 2.4×10^6 U.S. gals. (9100 m^3) which is about 60% greater than that needed for motorised flushing. Lack of water would thus be a major limitation on the speed of decontamination in districts with only firehosing equipment.

23. In a heavily populated district where buildings are often continuous on both sides of the street, there will be a significant reduction in the average dose-rate because of the areas already cleaned. The fractional reduction will depend also upon the depth of front gardens and the roof areas in line of sight from operations in the roadway. In the selected London district (Table 1) front gardens were 5 ft. deep and in 2 storey houses the amount of visible roof was equivalent to the addition of 15 ft. to either side of the road i.e. a centre strip of 40 ft. in a total equivalent width of 80 ft. would be cleaned and this should reduce the dose-rate ultimately to considerably less than half its original value. Since two and probably three out of the crew of four men/nozzle will be working most of the time manning the pump and hauling the hose in a

cleaned part of the road, an average protective factor of 1.25 has been assumed for men engaged in firehosing streets and pavements in a built-up area.

24. If the job had to be completed in a single shift of 8 hours, 50 nozzles, 200 men and a total rate of water consumption of 0.3 million U.S. gals/hour (1130 m^3/hour).

Table 5

Firehosing single 8 hour shift f = 1.25
50 nozzles 200 men

R_1 r.p.h.	K	Shift hours	Da r/man
3,000	.0063	H + 98 to H + 106	75
1,000	.0188	H + 37 to H + 54	75
500	.0375	H + 19 to H + 27	75

25. If 25 nozzles and hoses were available, the teams could work in two consecutive shifts for a dose of 150r, the length of each shift being arranged so that each gets a dose of 75r. Here $K_2 = \frac{150 \times 1.25}{5R_1}$ and $K_1 = \frac{75 \times 1.25}{5R_1}$.

The whole district could then be decontaminated in $\frac{2.92 \times 10^6}{25 \times 7.5 \times 10^3}$ or about 15½ hours.

Table 6

Firehosing Consecutive Shifts f = 1.25
25 nozzles 2 x 100 men

R_1	K_2	Consecutive Shift hours	K_1	Individual Shift hours
3,000	.0125	H + 89 to H + 104 (15 hours)	.0063 .0063	ΔT_1 7¼ ΔT_2 7¾
1,000	.0375	H + 32 to H + 47 (15 hours)	.0188 .0188	ΔT_1 6½ ΔT_2 8½
500	.075	H + 16 to H + 31 (15 hours)	.0375 .0375	ΔT_1 6½ ΔT_2 8½

D. Proposed British combined technique

26. This would be applicable to all but the heaviest fall-out deposits (i.e. much above $R_1 = 1000$). The decontamination would be carried out using a standard type road sweeping machine (without a collector box), which would sweep the fall-out into the street gutters and it would then be swept with firehoses down into the street drains: four 1½ inch firehoses (each with a ⅜ inch nozzle) could be fed by one existing type trailer pump of the British auxiliary fire service.

27. The road sweeper is assumed to afford protection by a factor $f = 3$. The rate of forward travel is normally just over 3 m.p.h. and assuming six passes over 40 ft. width of street and pavement and allowing about 25% of the time for servicing, the overall cleaning rate will be 80,000 sq. ft. per hour. The time required to sweep the whole area will be thus $2.92 \times 10^6/8 \times 10^4 = 36\frac{1}{2}$ hours.

28. Since firehosing in the open will follow behind the road sweeper it will not be realistic to start* decontamination earlier than about H + 16. For a one hour reference dose-rate, $R_1 = 1000$ r.p.h., Da = 75 $f = 3$, it can be estimated from Fig. 1 that three men each doing two 6 hour shifts with 12 hour rest period between, could sweep the whole area in about 36 hours getting doses of about 50, 40 and 30r respectively.

29. Firehosing would be started about H + 17: an average protective factor $f = 1.25$ (see paragraph 23) is assumed for men engaged in firehosing. A forward speed of about 1000 ft./hour per nozzle for driving fall-out along the street gutter down into the drains is considered to be reasonable. With one nozzle to each gutter and a paved width of 40 ft. this is equivalent to a cleaning rate of 20,000 sq. ft. per hour per nozzle.

30. One fire service trailer pump feeding 4 hoses and nozzles could keep pace with the road sweeper and clean the district in about 36 hours. In general, shifts of about 4 hours duration with a 12 hour rest interval will be preferable for this heavy manual work and unless illumination can be provided at night it will be desirable to limit firehosing to the hours of daylight.

31. Water consumption by the combined road sweeper and fire hosing technique would be $100 \times 60 \times 36 \times 4 = 0.86 \times 10^6$ U.S. gals or 3250 m^3 which, as one would expect, is considerably less than the amount needed either for the motorised flusher or for the firehosing technique alone.

32. If firehosing were carried out continuously with 4 nozzles from H + 17 to H + 53 (i.e. one hour behind the road sweeper), 9~~6~~ crews each of 16 men (total 144 ~~96~~ men) working in 3 or 4 hour shifts with 12 hours off, would be needed and of these, three ~~one~~ crews of 16 men would receive only about one ~~third~~ half of the allowed dose.

33. If firehosing were suspended during the night 5 crews of 16 men (total 80 men) using 4 nozzles could probably complete the decontamination by D + 3½ days - alternatively with two trailer pumps and 8 nozzles and 160 men, appropriate daylight shifts could be worked out from Fig. 1 to have the work completed by about D + 2½ days.

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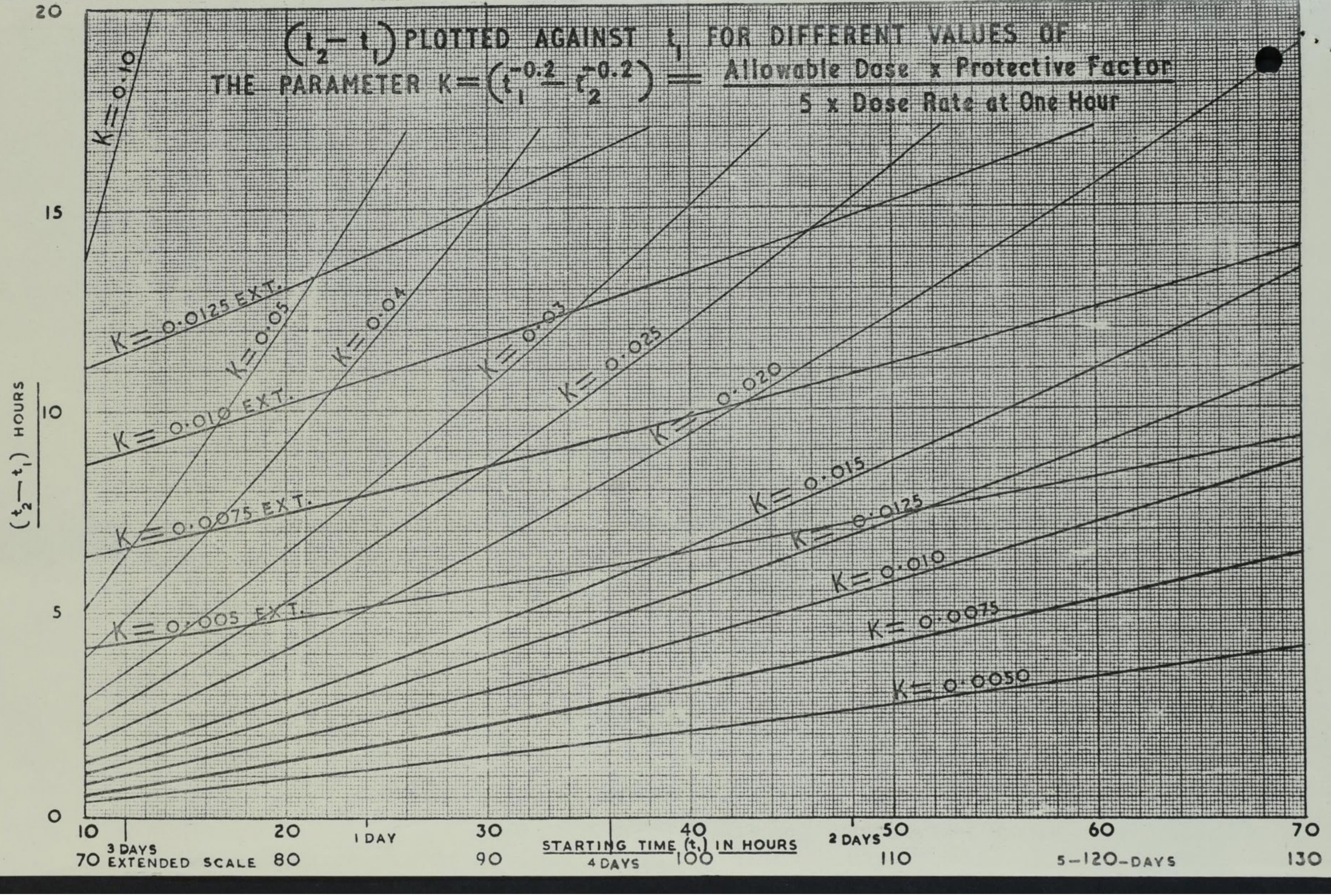
*In heavily contaminated areas the work should not start before 48 hours but shortage of equipment may make it desirable to start as soon as possible in some districts so that others will not have to remain contaminated for excessively long periods.

Table 7

Comparative Summary

Paved Area to be decontaminated
2.92×10^6 sq. ft. (= 27 hectares)
for R_1 = 1000 r.p.h. and Da = 75r

Technique	Equipment	Man hours	Time
A. Mechanised road sweeper (U.S.)	15 sweepers	15 x 8 = 120	H + 16 to 24
B. Motorised flusher (U.S.)	12 flushers	24 x 8 = 192	H + 24 to 32
C. Firehosing (U.S.)	50 Nozzles	200 x 8 = 1600	H + 37 to 45
D. Combined U.K. road sweeper, trailer pump and firehoses	1 sweeper 1 trailer pump 4 nozzles	3 x 12 = 36 9 x 16 x 4 = 596 total 612	H + 17 to 53



$(t_2 - t_1)$ PLOTTED AGAINST t_1 FOR DIFFERENT VALUES OF THE PARAMETER $K = \left(t_1^{-0.2} - t_2^{-0.2}\right) = \dfrac{\text{Allowable Dose x Protective Factor}}{\text{5 x Dose Rate at One Hour}}$

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Casualty Estimates for ground burst 10 Megaton bombs

AUTHOR: EDWARD LEADER-WILLIAMS, 1 OCTOBER 1956

1956

Summary

Tentative estimates of casualties from up to 45 ground burst 10 megaton bombs on British cities are estimated for various conditions of shelter and evacuation.

Casualties from an attack aimed in the optimum way (to cause casualties) when there is no shelter or evacuation are found to range from over 2½ million killed by a single bomb to just over half a million per bomb by 45 bombs. The total evacuation of the evacuation areas shown in Fig. 8 is found to reduce fatal casualties from this attack by from 99 to 84% depending on the number of bombs. Similarly the evacuation of the priority classes (45%) combined with the provision of a high standard of shelter for the remaining inhabitants of the evacuation areas would reduce fatal casualties from this attack by from 99 to 88% depending on the number of bombs. These are the maximum savings that could result from these policies. If the enemy adjusted his attack so that all his bombs were aimed at reception areas, thus achieving the maximum casualties among the evacuated and/or sheltered population, the reduction in fatal casualties would range from 62 to 44% for the policy of 100% evacuation, and from 79 to 65% for the policy of 45% evacuation combined with shelter. In the event of either of these policies being adopted the enemy would probably make some adjustments in his attack without going as far as in the limiting case above of aiming all his bombs at reception areas. The saving in casualties would then be intermediate between the two sets of figures given above.

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3. The shape and size of the fall-out pattern. The size and shape of the fall-out pattern for a ground burst 10 megaton bomb has been determined from the data presented at the February 1954 Tripartite conference*. The pattern consists of an ellipse with one apex at ground zero together with a circle centred a short distance down wind of ground zero. This pattern is reproduced as Figure 1 and the principal dimensions of some of its contours are shown in Table 1.

*** 15-19 Feb. 1954, "Tripartite Conference: Effects of Atomic Weapons on Human Beings and their Environment", Washington D.C., AFSWP & USAEC**

TABLE 1

Secret Principal dimensions of fall-out pattern from ground-burst 10 megaton bomb with a 15 knot wind

(This secret Tripartite conference included Canada, USA and UK.)

Dose rate (r/hr at 1 hour)	Down wind length of ellipse (miles)	Cross wind width of ellipse (miles)	Radius of ground zero circle (miles)	Down wind displacement of ground zero circle (miles)
5000	23	5.5	2.6	1.5
3000	33	7	3.1	1.7
2000	45	8	3.6	1.9
1000	72	11	4.5	2.3
500	115	16	5.7	2.6
300	160	22	6.8	2.8

Note: these data are from 1951 Jangle-S (1.2 kt) for downwind areas and 1952 Ivy-M (10.4 Mt) for upwind and crosswind of ground zero, with both distances and dose rates scaled by the cube-root of total yield (USNRDL-TR-1). This was incorporated into the June 1957 Effects of Nuclear Weapons edited by Glasstone. 1956 Redwing data showed upwind dose rates had been exaggerated 10-fold.

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IDEALIZED LOCAL CONTOURS FOR RESIDUAL RADIATION

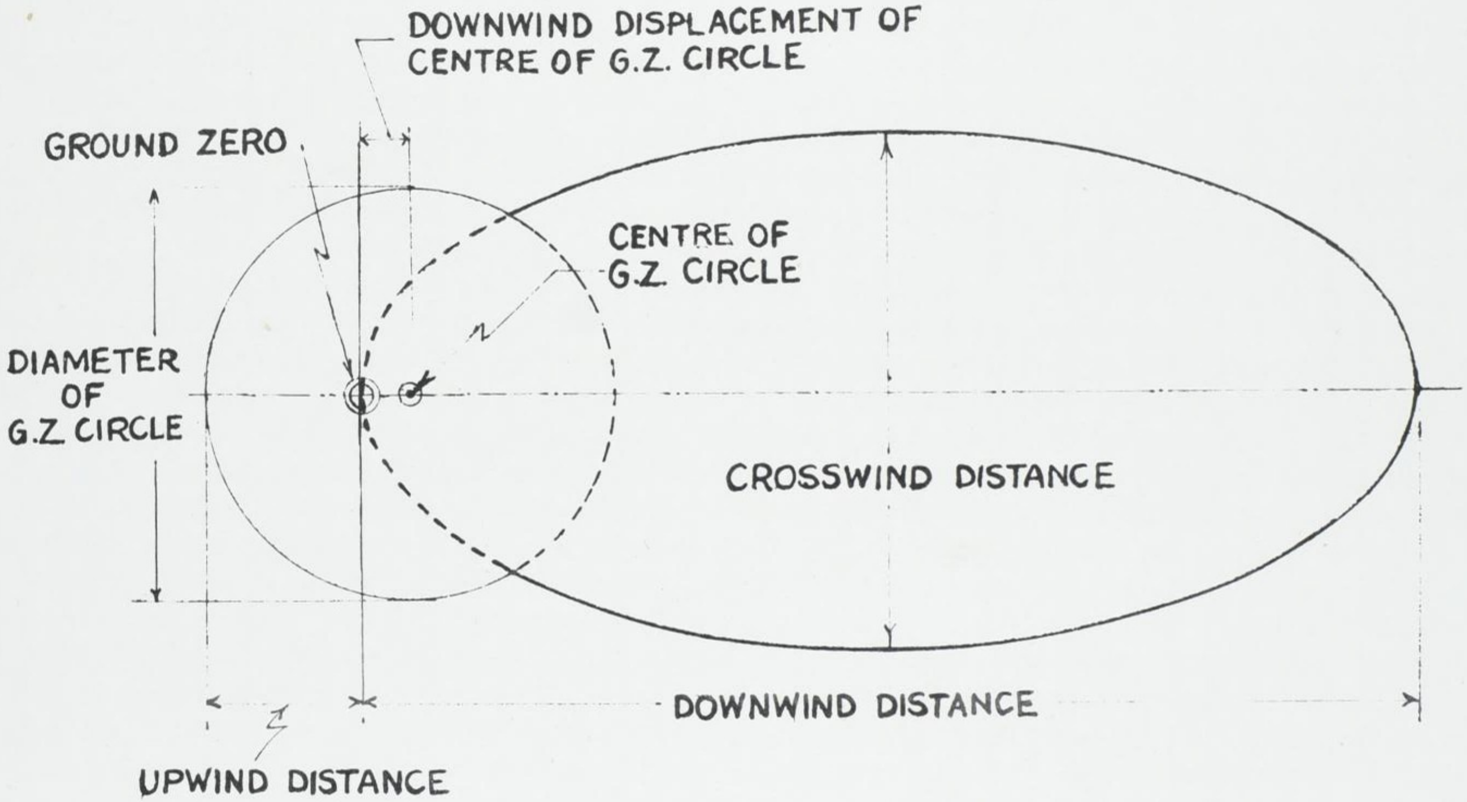

FIG. I

(As a result of changing USA supplied fallout data, the UK gave up analysing distances and just concentrated on the fallout areas contaminated under ~15mph wind speeds. This 1960 paper by Stanbury explains data sources!)

NOTE: these Confidential-classified reports by UK Home Office Scientific Adviser's Branch physicist George Reginald Stanbury, OBE (1903-73) refer to the 1957 edition of Glasstone's book Effects of Nuclear Weapons (based on nuclear test data for civil defence, not the false computer simulations later published).

Stanbury attended the 1952 Operation Hurricane UK nuclear test and analysed thermal and fallout data. This paper compares fallout areas in Glasstone and other sources like the Classified 1957 USA Capabilities of Atomic Weapons TM 23-200 and the 1959 UK Manual of C.D. v1 pamphlet 1, Nuclear Weapons booklet.

The latter shows that a 1 megaton fission surface burst gives 30 R/hr at 48 hours after burst over an area of ~50 square miles: this comes from Table 9.71 in Glasstone, 1957: the elliptical fallout belt for 15 mph wind is 22 miles long and 3.1 miles in maximum width, thus having an area of (Pi/4)(22)(3.1) = 52 square miles. For comparison, Fig. 4-14B in the Confidential American manual TM 23-200 Capabilities of Atomic Weapons, gives an area of just 28 square miles.

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Downwind fallout areas from ground-burst megaton explosions

1. Information available in 1958

(i) The U.S. publication "The Effects of Nuclear Weapons" paragraphs 9.71 to 9.73 GLASSTONE, 1957 edition

(ii) The U.S. publication "Capabilities of Atomic Weapons" fig. 4-4B, prepared by the Armed Forces Special Weapons Project; originally highly classified but now downgraded to "Confidential". This is at present under revision. TM 23-200

A comparison of the various figures for a few dose rates is given in Table 1.

Table 1

Areas of downwind contamination (sq. miles)

NOTE: at 1 Mt, TM 23-200 Capabilities gives half Glasstone's E.N.W. fallout areas for 300-3000 R/hr at 1 hr

Dose rate contour @ H + 1 r.p.h.	1 MT; 100% fission		10 MT; 100% fission	
	(i) E.N.W. & U.K. Nuclear Weapons	(iii) Capabilities	(i) E.N.W. & U.K. Nuclear Weapons	(iii) Capabilities
3000	54	27	540	650
1000	210	110	2100	1750
300	650	350	6500	5000
100	1500	1100	15000	18500
30	3300	3500	33500	43000

Difference

N.B. The Capabilities data is approximately summarised in the expression

$$AR = \frac{10^5}{p^{-1.2}}$$

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Where A = area in sq. miles
R = dose rate contour in r.p.h.
P = power of weapon in MT

NOTE: for 20 kt fission yield, Capabilities TM 23-200 Fig. 4-14A gives 80% of the fallout areas in E.N.W. 1957 for 10-3000 R/hr at 1 hr

---

(b) The fallout pattern (Triffet's Tewa fallout pattern from WT-1317.)

This is Fig. 7 on page 80 of the 1959 Congressional Hearings and is stated to be for a 5 MT explosion. No fission yield is actually given although, as the whole of the article in which this pattern appears is concerned with a 50% fission yield weapon, it seems reasonable to assume that this pattern is also intended for a 50% fission yield. (Redwing-Tewa, 5 Mt, 87% fission)

The 25 r.p.h., 100 r.p.h. and 500 r.p.h. contours have been integrated and the areas compared with those from Capabilities in Table 3.

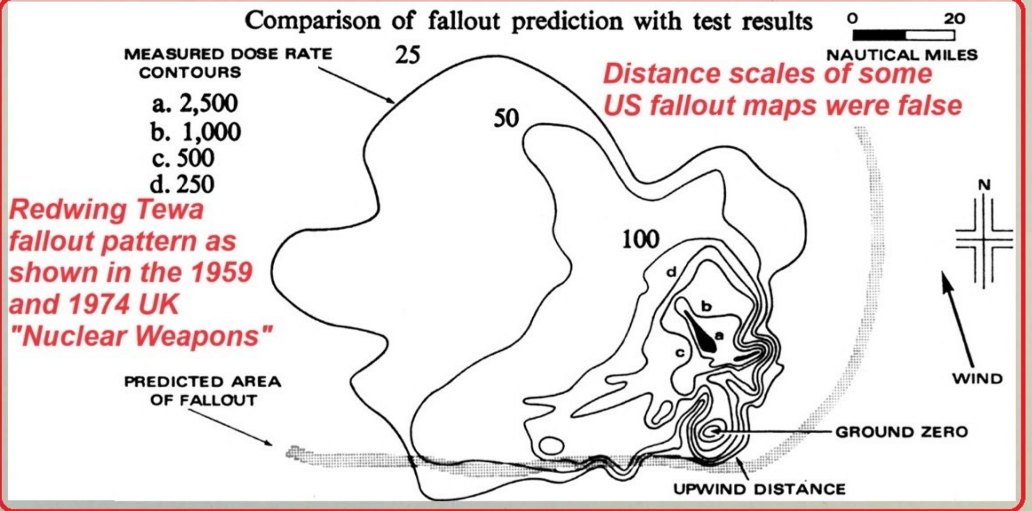
Table 3

Areas of downwind contamination (sq. miles)

Comparison of U.S. fallout pattern with Capabilities

Dose rate contour @ H + 1 r.p.h.	5 MT: 50% fission	
	Redwing-Tewa Fig. 7. p.80 1959 Hearings	Capabilities
500	2,000	750
100	6,000	3,300
25	30,000	12,000

NOTE: when the Capabilities data is corrected from 50% to the real Tewa fission yield of 87%, the REAL fallout areas are ~2 times Capabilities data, i.e. equal to the 1957 E.N.W. data!


Comparison of fallout prediction with test results

Distance scales of some US fallout maps were false

Redwing Tewa fallout pattern as shown in the 1959 and 1974 UK "Nuclear Weapons"

G. R. STANBURY

November 1960.

CONFIDENTIAL

Damage by nuclear weapons Min. of Aviation D1-57 March 1959. Confidential Discreet.

Western, A.M. Attenuation and scattering of initial nuclear radiation: measurements at Operation Buffalo. Tripartite Conference TCR 6-57 Home Office CD/SA 85 Sept. 1957.

Western, A.M. Attenuation and scattering of initial nuclear radiations A.W.R.E. Rep. T42-57 September 1957.

Radioactivity in the vicinity of the crater of a nuclear explosion NATO AC/158 - D/16 12th September 1962.

CD. 14029

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HOME OFFICE
SCIENTIFIC ADVISER'S BRANCH

Regional Scientific Adviser's Conference
15th-17th May 1962

The Soviet Strategic Air Threat to the United Kingdom

Mr. H. S. Young
(Deputy Director, Joint Intelligence Bureau)

Although the title of my Talk today is the strategic air threat to the United Kingdom, I thought it would be more useful to you, as Scientific Advisers to the Home Office, to talk about the strategic air threat to the West as a whole. The threat to the United Kingdom is all too easy to understand. It is, however, the threat to the West, as a whole, which determines the likelihood of war.

The Russian development of weapons since World War II falls into three natural periods. It must be remembered that, in general, Russia fought only land battles in World War II. She did not fight an air war or a scientific war, and therefore she found herself at a grievious disadvantage at the end. For the first five years of the post-war period she devoted herself to copying Western equipments, particularly those for air defence, i.e. radars and fighter aircraft. She also began building a large submarine force, but as these submarines were all of short endurance, this arm was clearly intended to play a defensive role against aircraft carriers rather than to attack our lines of sea communication. The whole accent during this period was on defence, and the only offensive items tackled in this period were the copying of the American B.29 Super Fortress, which became the Russian Medium Bomber TU4, and the outstandingly high class nuclear weapon programme which resulted in the first Soviet nuclear explosion in the second half of 1949.

The next five years may be classified as the "belt and braces" period. Russia continued to produce new marks of orthodox equipment whilst initiating research programmes on novel weapons. During this period she began research and development on guided weapons of all types, and began her work on nuclear submarines. Great emphasis was put on surface-to-air guided weapons, and this again emphasises her defensive outlook. Her first heavy bombers - the Bear and the Bison - appeared during this period. This was the first indication of a strategic offensive capability.

During the next six years she has been phasing out the older weapons in favour of new ones. The first ICBM was fired in the middle of 1957, and the first space vehicle was launched two months afterwards. Obviously, the Russians were very impressed by the political impact of the first sputnik and they subordinated the I.C.B.M. programme to that of sputniks and lunar probes for the next year. In the meantime, the production of heavy bombers continued at a very slow pace, and this, combined with the easy progress of the I.C.B.M., indicated that the Russians were in no hurry to develop a strategic offensive capability. Another most interesting development during this phase has been the missile submarine programme, and the Russians are devoting very great efforts to this weapon system.

The present Soviet air order of battle amounts to about 200 heavy bombers and about 2,000 light medium bombers. Taking the likely attrition rate into account, the threat that this presents to America is very small whilst the threat presented to the United Kingdom and NATO installations in Europe is exceedingly great. It is interesting to note that the number of Soviet day and all-weather fighters is about 8,000 which again emphasises her defensive outlook.

The missile threat has much the same character. The number of I.C.B.M. launchers available is probably less than 20, and there is no certainty that the Russians have any operational missiles at all. The number of intermediate range and medium range ballistic missile launchers probably amounts to about 300. Again, this poses a minor threat to the United States and a major threat to the United Kingdom and the NATO installations in Europe.

Bearing in mind that both sides almost certainly have an adequacy of fissile material, what does this all add up to? It probably means that the United States has a nuclear advantage of about 5 to 1. The quality of her deterrent is much higher, and there is much greater diversity. In terms of operations, it means that a Soviet first strike does not make sense, but an American first strike does. It means that Soviet strategy is:-

(a) Deterrence of the United States against cities, and

(b) Deterrence of Europe against everything.

On the assumption that the Soviets intend to continue their programme of I.C.B.M. production, they will certainly be able to have several hundreds of them in, say, five years. But it is far from certain that she intends to do this and, in view of the efforts which she is putting into her missile submarine programme, it may well be that, as with the heavy bombers, the number of land-based I.C.B.M's may remain small, and her major strategic missile threat may come from the se[illegible]

During the discussion which followed, Mr. Leader-Williams said that the figures given by Mr. Young for the USSR Order of Battle did not agree with the data produced for the US Congressional Hearings. Mr. Young stated that the figures he had presented were almost certainly more recent than those quoted at the Congressional Hearings. The US now agreed with JIB's assessment. Sir Charles Ellis asked how US and USSR I.C.B.M's compared with regard to accuracy at comparable ranges. Mr. Young said that they had insufficient data on USSR weapons to make a valid comparison. Whilst the fall of missiles had been observed, one could not be sure of the aiming point. From the small amount of evidence available it appeared that the C.E.P. at operational ranges is of the order of 1 to 1½ miles. Mr. Western asked where the 57 MT weapon fitted into the picture. Mr. Young said that we were not at all clear about this. It was delivered by the Bear and it was possible that the Russians had not yet developed a missile large enough to deliver it. It could possibly have been developed for Mr. Kruschev's Global Rocket. Its use in an anti-missile missile appears unlikely. Mr. Western asked if the Russians could deliver it to targets in the U.S.A. Mr. Young said that this was not possible with the Bear unless it could be refuelled several times en route. Mr. Garrard asked whether in view of their age we ought to disregard the TU-4's. Mr. Young replied that the TU-4 is probably obsolete and is being replaced by Beagle. Dr. Ollis asked how the attrition rates vary with the different methods of delivery. Mr. Young said that the US Air Defence would take a heavy toll of the Bear and Bison. The picture might change when the supersonic bomber came into service. The attrition rate by the UK Air Defence might well be lower. With regard to the ICBM, the USSR has a huge programme of Anti-ballistic Missile defence, but there are as yet no signs that missile sites have been constructed. The US is developing Nike-Zeus, but whether this will ever get into service is another matter. Its cost will be astronomical even by today's standards. In UK we consider the decoy problem to be insoluble. Now that the weight of megaton warheads can be much reduced, there is room in the missile for more decoy equipment. Warheads can be destroyed if the defence knows the design. Conversely, if the defence is known a warhead could be designed to outwit it. The problem is thus very complex and a successful solution is likely to prove very expensive.

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NOTE: this report follows from the "Report of a course given to university physics lecturers at the Civil Defence Staff College 8-11 July 1957" (UK National Archives doc. HO 228/21) which contains papers by Frank H. Pavry on blast data including height of burst effect curves, A. G. McDonald on the contribution of scattered thermal radiation (depending on the field of view of the sky), etc.

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SCIENTIFIC ADVISERS' BRANCH

REPORT OF A CONFERENCE OF THE REGIONAL SCIENTIFIC ADVISERS FOR CIVIL DEFENCE, HELD AT THE CIVIL DEFENCE STAFF COLLEGE, SUNNINGDALE PARK, 12th to 14th MAY, 1959.

October, 1959.

~~CONFIDENTIAL~~

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Report of a Conference of the Regional Scientific Advisers for Civil Defence, held at the Civil Defence Staff College, Sunningdale Park, 12th to 14th May, 1959.

The Conference was attended by Regional Scientific Advisers in England and Wales and Northern Ireland, by Regional Directors of Civil Defence and Officers of a number of Departments. The following were present for the whole or part of the proceedings:-

Scientific Advisers

Professor G. E. Coates, M.A., D.Sc., F.R.I.C.	Northern Region
Professor W. Bradley, D.Sc., Ph.D., F.R.I.C.	North Eastern Region
Professor L. F. Bates, Ph.D., D.Sc., F.R.S.	North Midland Region
Professor D. D. Eley, M.Sc., Ph.D., Sc.D.	" " "
Professor L. Hunter, D.Sc., Ph.D., F.R.I.C.	" " "
B. C. Saunders, Esq., M.A., Sc.D., D.Sc.	Eastern Region
Sir Charles Ellis, B.A., Ph.D., F.R.S.	London Region
Emlyn Williams, Esq., B.Sc., Ph.D., F.R.I.C.	" "
G. E. Watts, Esq., M.A., Ph.D., B.Sc., F.R.I.C.	South Eastern Region
N. Pentland, Esq., M.Sc., Ph.D., F.Inst.P.	" " "
E. G. Cowley, Esq., M.Sc., Ph.D., F.R.I.C.	" " "
H. W. Thompson, Esq., C.B.E., M.A., D.Sc., F.R.S.	Southern Region
Professor W. E. Garner, C.B.E., D.Sc., F.R.S.	South Western Region
Professor F. C. Frank, O.B.E., D.Phil., F.R.S.	" " "
J. W. Cook, Esq., D.Sc., Ph.D., Sc.D., F.R.S.	" " "
Professor G. K. Conn, M.A., Ph.D.	" " "
Professor F. Llewellyn Jones, M.A., D.Phil., D.Sc.	Wales
S. T. Bowden, Esq., D.Sc., F.R.I.C.	"
Professor M. Stacey, D.Sc., Ph.D., F.R.S.	Midland Region
Professor P. B. Moon, M.A., Ph.D., F.R.S.	" "
Professor J. R. Squire, M.A., M.D., F.R.C.P.	" "
A. F. H. Ward, Esq., M.A., Ph.D., F.R.I.C.	North Western Region
Professor J. Diamond, M.Sc., Wh.Sc., M.I.Mech.E.	" " "
Professor K. G. Emeleus, M.A., Ph.D.	Northern Ireland
Professor H. B. Henbest, B.Sc., Ph.D., D.I.C.	" "

Regional Directors

Major General S. Lamplugh, C.B., C.B.E.	Northern Region
J. R. S. Watson, Esq.,	North Eastern Region
Rear Admiral A. D. Torlesse, C.B., D.S.O.,	North Midland Region
Rear Admiral W. L. G. Adams, C.B., O.B.E.,	Southern Region
Major General J. S. Lethbridge, C.B., C.B.E., M.C.	South Western Region
Major General R. B. B. B. Cooke, C.B., C.B.E., D.S.O.	Wales
Air Marshal Sir Lawrence Pendred, K.B.E., C.B., D.F.C.	Midland Region
Lt. General E. N. Goddard, C.B., C.I.E., C.B.E., M.V.O. M.C.	North Western Region
Lt. General Sir Alexander Cameron, K.B.E., C.B., M.C.	South Eastern Region
Captain K. L. Harkness, D.S.C., R.N.	London Region

Home Office

Sir Charles Cunningham, K.B.E., C.B., C.V.O.
General Sir Sidney Kirkman, G.C.B., K.B.E., M.C.
Major General S. F. Irwin, C.B., C.B.E.
J. S. Paterson, Esq., C.B.E.
Lt. Colonel A. J. Batchelor, M.I.Mun.E., M.Inst.H.E.
K. P. Witney, Esq.
R. H. F. Firth, Esq.
M. G. Russell, Esq.
Major General F. R. G. Matthews, C.B., D.S.O.
Air Commodore C. J. Luce, D.S.O.
Surgeon Captain J. G. Holmes, O.B.E., M.A., M.D., R.N.(Retd.)
H. K. Black, Esq., B.Sc., Ph.D., D.I.C., F.R.I.C.
Miss I. M. Gibson

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Ministry of Supply

Sir Owen Wansbrough-Jones, K.B.E., C.B., M.A., Ph.D.

Ministry of Agriculture, Fisheries and Food

A. C. Sparks, Esq.
J. G. Carnochan, Esq.
G. Wortley, Esq., M.A., B.Sc.
Brigadier J. A. Mullington, O.B.E.

Ministry of Health

D. Thomson, Esq., M.D., D.P.H.
L. H. Murray, Esq., O.B.E., M.D., D.P.H.

Air Ministry

E. A. Lovell, Esq., O.B.E., B.Sc., A.Inst.P.

Admiralty

V. H. Taylor, Esq., B.Sc., A.Inst.P.

Ministry of Home Affairs, Northern Ireland

Captain C. C. McCreight, M.B.E.

Home Office, Scientific Advisers' Branch

R. H. Purcell, Esq., C.B., Ph.D., D.I.C., F.R.I.C.
E. Leader-Williams, Esq., B.Sc., A.M.Inst.C.E.
G. R. Stanbury, Esq., B.Sc., A.R.C.S., F.Inst.P.
D. T. Jones, Esq., M.A., B.Sc., F.S.S.
J. McAulay, Esq., D.Sc., A.R.T.C., A.R.I.C.
A. G. McDonald, Esq., B.Sc., A.R.C.S.
T. Martin, Esq., M.Sc., D.I.C., F.Inst.P.
A. M. Western, Esq., M.A., B.Sc.
A. D. Perryman, Esq., B.Sc.
E. Hutchings, Esq.
Miss H. Duddy

PROGRAMME OF THE CONFERENCE

Tuesday, 12th May

	Conference Assembles	
20.30	Introduction by the Under Secretary of State	Sir Charles Cunningham
	Science and Defence, past, present and future	Sir O. Wansbrough-Jones

Wednesday, 13th May

09.30	Welcome by the Commandant	Major General F. R. G. Matthews
09.35	Opening Address by the Chief Scientific Adviser	Dr. R. H. Purcell
09.45-11.00	Working Party on the Operation of Scientific Teams at Region and Below.	
	(i) Introduction of the First Report on Operations at Regional level.	Dr. R. H. Purcell
	(ii) Discussion of the Report by Regional Scientific Advisers and Regional Directors.	
11.00-11.20	COFFEE	
11.20-12.20	Part III Training of Scientific Intelligence Officers	
	(i) Regional Courses and Exercises based on the Easingwold Course.	Mr. T. Martin
	(ii) Local Authority Exercises, Exercise "Arc".	Mr. E. Leader-Williams
12.20-12.45	Summing up of the morning's proceedings by the Director General	General Sir Sidney Kirkman
	LUNCH	
14.15-14.35	Radiation Tolerance Doses in Civil Defence. Position reached since the last Conference	Mr. G. R. Stanbury
14.35-15.15	Deployment of Civil Defence Forces in relation to Radio-activity.	Mr. E. Leader-Williams
15.15-15.45	The Operational Implications of Serial 8	Mr. K. P. Witney
15.45-16.15	TEA	

Wednesday, 13th May (contd.)

16.15-17.10	Study "Pikadon". Presentation of the position at Sub-Region at H + 2 and H + 4 following a $\frac{1}{2}$ M.T. bomb on Newcastle.	Staff College
17.10-17.45	Discussion of Serials 7 - 10.	Mr. G. R. Stanbury to open

Thursday, 14th May

Scientific aspects of the Problem of living in an area contaminated by Radio-active Fall-Out.

09.30-10.00	(i)	Survey of Protection against Fall-Out afforded by Houses and other Buildings.	Mr. D. T. Jones
10.00-10.30	(ii)	Radio-active Decontamination.	Dr. J. McAulay
10.30-11.00	(iii)	Discussion on Serials 12 and 13.	
11.00-11.30		COFFEE	
11.30-12.15	(iv)	Food and Agriculture	Mr. G. Wortley
12.15-12.45	(v)	Food Monitoring	Brigadier J. A. Mullington
		LUNCH	
14.15-15.00	(vi)	Discussion on Serials 15 and 16.	
15.00-15.45		Fire Problems after a Megaton Explosion Study "Torquemada".	Mr. G. R. Stanbury
15.45-16.00		Conclusion	
16.00		TEA. Conference disperses.	

MR. LEADER-WILLIAMS: We certainly may be, but a limit would soon be reached because of the time taken in giving first aid and in delivery to the ambulances.

DR. PURCELL: I would have thought that Professor Squire was absolutely right in saying that we must make more use of private motor cars to carry the injured.

DR. MURRAY: I imagine the figures quoted do not include private cars; possibly they could be used.

MR. WITNEY: We were working on that basis. The station-wagon type of car could certainly be used, and ordinary cars could be used for sitting cases.

Thursday, 14th May.

XIV MR. JONES described a Survey of the Protection against Fall-out afforded by Houses and Other Buildings. He said:

This work was begun in 1956 when the White Paper on Civil Defence (Cd 9691) called for a sample survey to be made to find the level of protection against fallout which houses and other buildings could provide. The survey of private houses was started in 1957 and has now been completed. You will have had a paper describing the results of that survey - CD/SA 89.

Private Houses. The Home Office obtained the co-operation of the Local Authorities in eleven urban and rural districts which were considered to represent typical reception areas in the country. None of the large conurbations was included: the populations in all cases were less than 100,000, in most cases considerably less. The districts were:

Carlisle, Chesterfield, Exeter, Harrogate, Kirkcaldy, Perth, Wellingborough, Wrexham, Chelmsford, Witney and St. Boswells.

The Authorities were provided with a table which gave the protective factors of typical houses. Their task was to take a census of houses of various types and render a return of the number of households having given protective factors. On the whole the results showed that factors were lower than expected. The table on page 5 of CD/SA 89 shows that many households would have factors less than 40.

The Authorities were asked to consider three possible schemes of protection. Under Scheme A householders would stay in their own dwellings; under Scheme B they could move, if they occupied part of a building such as a flat, into the best part of the building; and under Scheme C they would make use of an underfloor trench in their own premises - if this were feasible.

Some of the outstanding results showed that in rural districts 45% had factors less than 25, 40% less than 40, and 97% less than 100. For rural districts under Scheme C, the corresponding percentages were 35%, 57% and 76%. In urban districts the corresponding precentages were 31%, 57% and 90% under Scheme A, and 11%, 40% and 52% under Scheme C. Combining rural and urban districts with appropriate weighting we found 'natural' estimates under Scheme A to be 36%, 64% and 95%; and under Scheme C to be 21%, 46% and 61%. There was some improvement in rural and urban districts in Scheme B and Scheme A, but on the whole this was very slight.

In some areas it was found that the factors at the centres of towns were distinctly higher than at the outskirts. In Chesterfield, for example, there was a marked difference, but in Kirkcaldy there was not much difference.

Communal Buildings. The Survey of communal buildings, that is buildings other than private houses which could be used as shelters, was begun in November last year. There were buildings such as theatres, churches, schools, office blocks, department stores and so on, which could accommodate large numbers of people. This work is not complete, but some interesting results have already been received.

XV **DR. McAULAY** gave a review of progress in Radioactive Decontamination. He said:

It is three years since we last reviewed the problems of radiological decontamination. Of the few papers which have come in the first is one from the Chemical Defence Experimental Establishment - PTP (R) 20, which gives an account of their experiments on Decontamination of Skin and Clothing. There are two American papers that you might like to study at your leisure. One of them is a paper by the staff of the Stanford Research Institute under contract to the Office of Civil and Defense Mobilisation - CD 11727 - entitled 'Systems Analysis of Radiological Defence'. The other one is a report on 'Operation Plumbbob' - American Atomic Energy Commission - CD 11605. There are two other papers that I want to refer to - one is the very voluminous report on The Radiological Recovery of Fixed Military Installations, which seems to be based on questionably high effectiveness in cleaning up surfaces. The chart shows the residual number, i.e. the activity remaining after decontamination. We are rather doubtful about all these figures and particularly about 95% clean up of a concrete road by fire-hosing. The other report is by Technical Operations Incorporated - Radiological Defence Planning Guide. This particular group was asked to produce a complete defence plan for O.C.D.M., but their work is based on the same data which appear to relate entirely to large particles from bursts on desert sand, and easy to remove by simply blowing or washing them away.

Coming to the problem of the removal of contamination from skin, clothing, vehicles or equipment, this is a secondary problem because it is difficult to imagine conditions where the radioactive dust hazard could be serious without simultaneous lethal gamma exposure. In spite of high standards of personal cleanliness you may later get a Beta burn, but it is still only a burn. The main object of decontamination of skin and clothing is to keep the Operating Theatre clean and to keep contamination from getting into wounds or into food and drink. The first problem that Porton faced was to get a suitable simulant for fall-out. They produced a simulant consisting of glass microspheres impregnated with 0.15% Ta and these were irradiated in a pile to roughly .1 mc/gm. The microspheres were 10 to 100 microns in size which is the biggest they can make. The 10 micron particle represents something much more difficult to remove from skin and clothing than the kind of particle Mr. Stanbury was talking about, i.e. fall-out particles of 75 microns and above.

Then they had the problem of getting live skin, which was difficult, so they made a skin replica by taking an epoxy resin cast and from this they obtained a positive using a solution of methyl nylon in chloroform and alcohol. The replica gave a good representation of the mechanical surface of human skin. Porton found that with particles of 10 to 100 microns, by using ordinary soap and water, they could get effectively over 98% removal. In the case of clothing contaminated with these glass microspheres they found brushing or shaking ones jacket is not a very effective way of removing these particles - less than 60% in some cases - so they tried washing with detergents. I cannot imagine anyone doing this with a suit, but with washable fabrics over 98% was removed in this way. The fabrics were placed in the tub or in a washing machine and stirred about 100 times. In the case of outer clothing they naturally felt this was not desirable so they tried vacuum cleaning and got more than 98% removal.

Before going on to the question of decontamination of areas, there is one very important piece of real factual evidence I wish to mention. If a particle say of earth - 200 microns - is sucked up into the cloud, and fission products condense on it, and if that particle gets wet coming down, the activity after about 10 minutes becomes, to a large extent, fixed in the particle. Also, if the particle comes down on to a wet surface, and is wet for 10 minutes, the amount of transfer is likely to be negligible. Except for water bursts our problem is going to be very largely a mechanical one of removing the particles from the contaminated surface.

Now area decontamination. Here we are faced with the problem of a heavily contaminated built-up area, and what to do after 48 hours. We have to decide for instance, whether it is going to be worth while to clean up roads, pavements, roofs etc. and when we ought to do the jobs. We have not got very clear answers to this problem in spite of the voluminous reports from America. The experimental work in the U.K. is being done by Porton who have recently acquired a road sweeper and various other items of equipment needed to clean up an area. They will carry out trials as soon as supplies of suitable simulant are available.

Let me go back to two years ago. Many of you probably read the Report of the Physics Lecturers Course. There I reviewed the problem and the many factors involved on which we have no accurate data. A number of factors were combined into one Parameter:-

$$N = \frac{PX\ T(25)}{2L}$$

where P is the resident population, X in feet per hour is the rate of clean up of a street, L the total street length to be cleaned, and T(25) the time in hours the operators could work before getting a dose of 25r. N represents the number of residents per operator required for decontamination. Thus if decontamination were started at 2, 4 or 6 days after the burst, the values of N would range from 185 to 370, from 500 to 900, and from 800 to 1,500. Now I assumed in doing the decontaminating that people came from outside to operate the road-sweeping equipment. Just before that, one person in each house came out for not more than half an hour and brushed all the contamination from the pavement and sidepaths into the street gutter. Following on the road sweepers which swept the fall-out into the street gutters, a water tank and pump enabled the contamination to be washed along the gutter and down the drain. It is interesting to note that in one of the American Operational Research reports the range of effort covered is one operator per 100 of the population up to one per thousand. The U.S. report - Radiological Recovery of Fixed Military Installations - gives some figures about rates of cleaning up. They assumed motorised flushing equipment, graders which scrape the earth into a windrow pile and leave it at the side, scrapers which lift up this windrow and put it into a container so that it can be moved and dumped somewhere else. They used bull-dozers, ploughs, and so on. They give the rate for fire hosing a street as 6,000 gallons per hour at 80 p.s.i. through each of two 1½ inch hoses and four men to each hose, or 7,500 sq. ft. per hour per hose. In the case of motorised equipment, i.e. the water flushing machine with two very powerful nozzles in front - this delivered 50,000 gallons per hour at 90 p.s.i. employing two men and decontaminating some 35,000 sq. ft. per hour. In the Plumbbob report the calculations were something of the same order - an unpaved area of 500 ft. X 500 ft. = 250,000 sq. ft., was decontaminated in three hours or 80,000 sq ft. clean up per hour. In my case I estimated the rate of street cleaning with a road sweeper and firehosing at between 40,000 and 150,000 sq. ft. per hour, assuming that contamination is washed down into street drains.

Now let me come to the Stanford Research Institute's study. They worked out what is called a 'methodology' for assessing the value of a decontamination procedure. Unfortunately they used a complicated basis of assessment, first a 'performance' value which is the rate of coverage multiplied by the fractional reduction of radiation divided by the exposure factor. From this they worked out a 'decontamination' value, which is the performance value multiplied by the fraction of open field radiation penetrating a shelter divided by above-ground area per capita. The results work out very much in the same range as we calculated. Two cases are assumed (a) 1 operator per 100 of the population, and (2) 1 operator per 1,000 of the population. The bulk of the effort is done by mechanised equipment but the population are expected to do a bit of spade work on unpaved areas. In the paper they give very interesting data on the distribution of certain types of surface in American towns and the proportion of certain classes of people likely to be available and useful for undertaking the decontamination. Assuming one operator per hundred of the population, a 50% dose rate reduction could be achieved if each member of the crew worked two 10-hour shifts, and a 90% dose rate reduction if each worked twenty 10-hour shifts. In my assessment I took only 25r as the limit of exposure for people engaged on decontamination. I must now go back and do it again for a wartime emergency exposure of 75r if this is justified to enable the community to survive. I might add that this particular SRI report - if anybody is interested enough to read it - has a beautiful graph. It shows the cost of saving the United States of

America in relation to the actual cost of the protective decontamination programme, in terms of the surviving population.

It is interesting to note that in an average American town, per 1,000 inhabitants there are 0.7 Sanitary Department employees, one fireman, 2.9 highway department workers, 1.4 policemen. These with watchmen and cleaners make up 1.8% of the total population possibly able and available to do this job. They have also considered that in America, of course, all cars would have their tanks at least half full in emergency - that means something like 10 hours travelling at 25 miles an hour, so everybody could beat it out of the contaminated area for some 250 miles. Each would have to take his own food, and this is where the Stanford Institute's estimate stops. They say they can carry the operation no further because they do not know what would happen when the family food supplies ran out.

I would like now to refer to the extremely valuable factual report on Operation Plumbbob in 1957. The report is called the 'Evaluation of Countermeasure System Components and Operational Procedures', but I don't think one ought to let the title frighten us away from the value of the report. They built an underground magazine type shelter about 25 ft. in the middle by 48 ft. long, covered with 3 ft. of earth, and they carried out a study of the dose rates during gamma flash and residual effects inside and outside the shelter to several days after the burst. It had large ventilators and one of the objects was to study the internal dose at various points inside in relation to the various apertures of the shelter. In the second part of the programme - three areas outside were selected as likely to receive fall-out. In one of the shots this particular shelter was almost a mile from Ground Zero. After the shot the fall-out built up over the shelter very rapidly - it started in about six minutes and it reached a maximum in 15 minutes from the burst. The maximum was 60 r.p.h., which is higher than they had budgeted for. It had been intended that a party should come out from the shelter to monitor the areas and to decontaminate one of the selected areas seven hours after the shot, but in an area at 60 r.p.h. at 15 minutes after burst, this was not possible until two days after and it presented a very valuable opportunity as the area was thoroughly monitored before and after decontamination and all personnel carried film badges. Three areas had been marked out, and at 7 hours after burst monitors were sent out to measure the dose rate at the centres of the three areas. One area which had a fairly high dose rate of 3 r.p.h. at 7 hours was selected. The area was a square of 500 ft. side. Two days after the burst four monitors went out and started at the centre and proceeded in steps to each corner, and the whole area was very thoroughly monitored at heights above the ground of 1 ft., 2 ft. and 3 ft. Another monitor went to various points outside and measured the dose rates so that we have a complete record of all relevant dose rates before, during and after the decontamination operation. The crews and their equipment consisting of four motor graders (pushing the earth to the side into windrows), two motorised scrapers, and one bull-dozer was kept three miles from G.Z. in a clear area. Decontamination was done in four stages and took three hours. In the first stage an area of 40 ft. X 40 ft. was cleared and then an additional 20 ft. round the periphery. This was then extended to 100 ft. X 100 ft. and finally to 500 ft. X 500 ft. The central area of 100 ft. X 100 ft. was monitored and rescraped in an attempt to get down to a residual number (R.N.) of 0.01, i.e. 99% dose rate reduction at the centre. However this was not achieved. The results at 3 ft. height were:-

Area	R.N. at Centre (average)
40ft. X 40ft.	0.39
60ft. X 60ft.	0.32
100ft. X 100ft.	0.24
500ft. X 500ft.	0.16

A second pass over the 100 ft. X 100 ft. area gave an R.N. of 0.11. The ground was rough and hard and a lot of boulders had to be removed which slowed them down very considerably.

wanting to go into the middle of a Z zone for the food there until considerably later, and it does look on a first analysis as though his tasks will develop im a fairly orderly way.

BRIGADIER MULLINGTON: I see him starting fairly early. The Regional Food Controller will be edging round to see where he can get food from for areas badly hit.

DR. PURCELL: Well I quite agree with that, but I am equally convinced that his movements will be limited by the public control conditions and the gradual clearance of the zones. Could I ask you to continue to turn this problem over in your minds and let me have any considered opinions that you may have by correspondence; that is the best conclusion for this afternoon.

III MR. STANBURY gave a talk on Study Torquemada, dealing with Fire Problems after a Megaton Explosion. He has provided the following summary:-

I. Estimation of initial fire incidence

The method used is based on that described in the Report of the Technical and Tactical Study Courses held at the Fire Service College in May, June and July 1952 entitled "The Fire Situation after an Atomic Attack on a British City" - a copy of which can be made available on application.

The British city concerned in these particular study courses was Birmingham and for this purpose a 1 in 12 scale model was made by the Birmingham Fire Brigade covering a 25° sector of the area likely to be affected by the explosion of a nominal atomic bomb over the centre of the city. With this model the problem of shielding - which is all important in this connection - could be dealt with quite satisfactorily. A lamp was set up at the point of burst in relation to the model, and it could be seen immediately which windows were exposed and which were shielded. After that it was only a question of estimating the chances of the development of continuing fires in relation to the fire risk and size of the fire compartment concerned by the methods described in detail in the report.

In this study we were concerned with the much larger area of damage produced by a 1 MT explosion, and we had no model. We are forced therefore to use maps and the most detailed maps available were the Insurance Plans of Liverpool and Birkenhead prepared by Messrs. C. E. Goad Ltd., which were hired specially for the purpose. These are to the scale of 40 ft. to the inch and they give complete details about road widths, height of buildings, construction etc. In order to reduce the volume and tediousness of the work involved in using maps the method developed for the Birmingham model had to be substantially simplified.

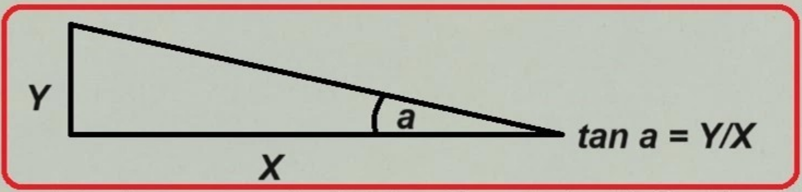
Effect of Shielding: Estimation of the Number of Exposed Floors

Assuming that buildings on opposite sides of a street which is receiving heat radiation from a direction perpendicular to its length are of the same height, then the number of exposed floors on the front of the buildings on the side of the road away from the explosion depends on

(a) the angle of arrival of the rays, say α and

(b) the width of the street = 10w

Where w = number of units of 10 ft.



If we take the average depth of a floor to be 10 ft. then the number of exposed floors is given by

$$\tan \alpha = \frac{10n}{10w} \qquad \text{or } n = w \tan \alpha$$

For a 1 MT groundburst bomb the height of the top of the fireball above ground is about 0.72 miles. Because this distance is large compared with the height of most buildings, the exposed upper floors do actually see a large part of the fireball and not just the top of it, but in assuming that the radiation is just as intense from the top as from the middle we are probably overestimating the fire situation which will result.

On the above basis the following table gives the number of exposed upper floors (to the nearest $\frac{1}{2}$ floor) for a range of distances from the explosion and a range of street widths.

Hence at 5 miles from 1 megaton ground burst, only top windows are exposed

TABLE I

Distance from explosion	Angle of arrival	tan α	Width of street (units of 10 ft.)						
miles	α°		2	3	4	5	6	7	8
1	35	.72	1.5	2	3	3.5	4.5	5	6
1½	26	.48	1	1.5	2	2.5	3	3.5	4
2	20	.36	.5	1	1.5	2	2	2.5	3
3	13½	.24	.5	.5	1	1	1.5	1.5	2
4	10	.18	.5	.5	.5	1	1	1.5	1.5
5	8	.15	.5	.5	.5	.5	1	1	1
6	7	.12	-	.5	.5	.5	.5	1	1
7	6	.1	-	-	.5	.5	.5	.5	1

It is obvious that for street widths greater than 80 ft. at close ranges (or for example where there is an open space in front of a building) it can be immediately assumed that all floors are exposed; since few buildings have more than 5 or 6 floors. At the extreme range for ignition the angle of arrival varies so slowly that for street widths greater than 80 ft. the number of exposed floors can always be taken as one. It is for these reasons that the Table is stopped at 80 ft.

To the numbers obtained from Table I must be added or subtracted the differences in numbers of floors of opposing buildings as shown on the maps to give the actual number of exposed floors in any particular case. This number of course cannot be negative, nor greater than the total number of floors in the building exposed.

Variation with Range

In the Birmingham study an attempt was made to allow for the variation in intensity of the radiation, with distance from the explosion on the chance of ignition, but the foundation for this was not very sound. In this study it was assumed -

(a) that there are no continuing fires inside a circle 1 mile in radius because of the complete collapse of all buildings

(b) that out to 1½ miles the only fires possible are those in buildings of steel framed or reinforced concrete construction

(c) that the chance of ignition is 100% all the way from 1½ miles to 5 miles, after which it drops to 30% for a further 2 miles. [At 7 miles from a 1 MT explosion the heat intensity is still 12 cal/sq.cm which is sufficient to ignite easily inflammable material like "Excelsior".]

Inclination of Streets to the Direct Line of the Heat Flash

The first two lines of the following table are taken from the Report already referred to.

TABLE II

Angle between heat flash and street (degrees)	90-75	75-60	60-45	45-30	30-15	15-0
Proportion of heat flash entering windows %	99	92.5	80	60	40	14
Proposed grouping for Torquemada	100%		80%		Nil	

For working with Goad Maps, the division into 6 angular groups is too cumbersome, and it was decided to use the 3 group system shown in the last line. This means that all streets inclined at an angle greater than 60° to the direction of the flash are assumed to be at right angles to it; all those between 30° and 60° have their chances of ignition reduced by 20%; and those below 30° are neglected. A small pilot study of one area showed that this approximation was very close, while the saving in work was considerable.

The chance of a continuing fire as affected by (a) Size of Fire Compartment and (b) Number of Windows.

This was dealt with in great detail in the earlier report, but considerable simplification was needed for use with the Goad maps.

The chance of a continuing fire developing from a small source of ignition decreases with the size of the fire compartment and increases with the number of sources of ignition i.e. with the number of exposed windows, and these were dealt with separately in the Birmingham model assessment. However, the decrease with size is roughly proportional to the area and the increase - because of windows - to the length (assuming an approximately square building). The overall effect is that the chance is inversely proportional to the length of the exposed front of the building.

In this study the chance has been still further reduced by two assumptions

(a) that 25% of the windows have been whitewashed and

(b) that 25% of the incipient fires are extinguished by fire guards giving an overall reduction of the chance of fire of 55% (75% x 75%).

Owing to the uncertainly connected with this part of the estimation there seemed to be no point in using more than 3 main fire compartment size groups and the figures finally adopted were as follows:-

Group (A)	20 ft. frontage.	Chance	0.2
Group (B)	40 ft. "	"	0.1
Group (C)	80 ft. "	"	0.05

In the streets inclined between 60° to 30° to the heat flash, these chances were reduced by 20% to

Group (A)	0.16
Group (B)	0.08
Group (C)	0.04

The Method of Estimation

The following routine method was adopted for making use of the principles enumerated above.

1. For any particular sheet of the Goad maps, the distance of the centre of the street to ground zero was first estimated to the nearest mile.

2. From the N/S pointer on the sheet, the direction of the flash was determined and the streets perpendicular to this (within 30°) were noted.

3. Starting from one end of each street, each exposed fire compartment was considered in turn and the number of exposed floors marked on a tracing paper overlay, using Table I together with the information on the numbers of floors of opposite buildings given on the map.

4. All the fire compartments in Group (A) were then noted and the number of exposed floors for each was multiplied by the chance of a continuing fire developing (0.2 in this case) and the number recorded on the overlay in Green. The fire compartments in Group (B) were dealt with in a similar way and the number recorded on the overlay in Yellow. Finally the fire compartments in Group (C) were dealt with, and the chances recorded on the overlay in Red.

5. This process was repeated for the buildings in the streets inclined between 60° to 30° to the flash, but using the appropriately reduced chance figures.

6. All the figures in each of the colour groups were then added to give the total chance that continuing fires would be started on any one floor of any one building for each group of fire compartment sizes. Let us assume that these numbers are x, y and z. Then these numbers of fires were marked in on the overlay as red ticks, the actual choice of which building in each group being immaterial.

Inevitably there were many classes of buildings which did not respond readily to the above method of analysis, and each had to be considered on its merits, bringing into play as much wartime experience in this field as was available to the Branch.

Secondary fires

The problem of so-called "secondary" fires i.e. - those started as a result of disruption of some kind or another caused by the blast - was dealt with in great detail in a paper entitled "The Fire Risk from Blast Damage" which also appeared in the Fire Service College Report already referred to. This was based on a careful study of all the fly bomb records. It was found that about 6% of the bombs were responsible for large continuing fires and about 40% for small fires in debris most of which went out of their own accord. If we assume that one tenth of the small fires continue the overall figure for continuing fires is 10%. In a groundburst 20 KT bomb, the damage produced is equivalent to that of about 1,250 fly bombs. For a 1 MT groundburst the number would be -

$$1{,}250 \; \frac{(10^3)}{(20)} \; . \; {}^2/_3 \; = \; 50{,}000$$

and if 10% of these cause fires, there will be 5,000 secondary fires.

It is not expected that this type of fire would occur beyond six miles since this is the limit of damage. Thus secondary fires might occur on the average at a ~~desnity~~ density of $\frac{5000}{\pi 6^2}$ = 40/sq. mile.

Each Goad Map covers an area of approximately 1/40th sq. mile so that on each map one extra fire must be included. Here again it is not important where fire is located, but it is reasonable to select a high fire risk occupancy such as paint ~~sotre~~ store, a furniture factory, or a garage.

II. Estimation of Fire Spread

In the area of Liverpool and Birkenhead covered by the Goad Maps, the numbers of fires at H + 1 turned out to be as follows:-

Fire Compartment Size	Number
Small	1050
Medium	223
Large	20
	1293
Secondary fires allocated in roughly the same proportion	180
	1473

The area not covered by the Goad Maps was largely residential so that most of these additional fires were in the small compartment category.

The total number of fires was between 7,000 and 8,000, and it was decided to allocate the following round numbers to each category:-

Small (S)	7,000
Medium (M)	500
Large (L)	50
Total (N)	7,550

From last war experience of mass fire raids in Germany it was concluded that the overall spread factor was about 2; i.e. about twice as many buildings were destroyed by fire as were actually set alight by incendiary bombs; thus the assumptions adopted must allow for the final destruction by fire of about 15,000 buildings which is about 1 in 10 to 1 in 15 of all the buildings in the area.

For the purpose of assessing possible spread let us assume -

Proportion of fires in each category which burn out without spreading $= p_1$

Proportion of fires which spread to one other building $= p_2$

" " " " " " two " buildings $= p_3$

" " " " " " three " " $= p_4$

In each category $p_1 + p_2 + p_3 + 4 = 1$ and the final number of buildings destroyed by fire =

$$S\,(p_1 + 2p_2 + 3p_3 + 4p_4)s$$
$$+ M\,(p_1 + 2p_2 + 3p_3 + 4p_4)m + L(p_1 + 2p_2 + 3p_3 + 4p_4)l$$

As a first shot the following numbers are suggested:-

	Fire Compartment Size		
	Small	Medium	Large
p_1	.6	.25	.1
p_2	.2	.25	.2
p_3	.1	.25	.3
p_4	.1	.25	.4

This gives:-

> Final number of buildings destroyed by fire = (7,000 x 1.7) + (500 x 2.5) + (50 x 3.0) = 13,300 which is near enough for this purpose.

In order to estimate the number of fires burning at any given time it was necessary to make further assumptions about

(a) burn-out times and

(b) starting times for first, second and third spread fires.

The following are suggested:-

	Fire Compartment Size		
	Small	Medium	Large
Burn-out time from ignition (hours)	$1\frac{3}{4}$	$3\frac{1}{2}$	7
Starting time for			
1st-spread fires	H + $1\frac{1}{2}$	H + $1\frac{1}{2}$	H + $1\frac{1}{2}$
2nd- " "	H + 3	H + 3	H + 3
3rd- " "	H + $4\frac{1}{2}$	H + $4\frac{1}{2}$	H + $4\frac{1}{2}$

These two sets of assumptions, combined with the actual numbers of fires in each category were then used to calculate the fire position at various times after H + 1 as follows:-

Time After Burst (hours)	Origination of Fire	Fire Compartment Size					
		Small		Medium		Large	
H + 1	Initial heat flash + secondary fires	7,000		500		50	
H + 2	Initial fires	Nil	2,800	500	875	50	95
	1st spread fires (p2 + p3 + p4)	2,800		375		45	
	2nd " " (p3 + p4)	Nil		Nil		Nil	
	3rd " " (p4)	Nil		Nil		Nil	
H + 4	Initial fires	Nil	1,400	Nil	625	50	130
	1st spread fires (p2 + p3 + p4)	Nil		375		45	
	2nd " " (p3 + p4)	1,400		250		35	
	3rd " " (p4)	Nil		Nil		Nil	
H + 8	Initial fires	Nil	Nil	Nil	125	Nil	100
	1st apread fires (p2 + p3 + p4)	Nil		Nil		45	
	2nd " " (p3 + p4)	Nil		Nil		35	
	3rd " " (p4)	Nil		125		20	

These numbers were divided between the various fire areas in the Liverpool-Bootle district using the H + 1 assessment as the basis. The local fire officers with their special experience of the fire risks in their areas, allocated the positions and determined where the fire spread was most likely to take place. This work, which was most painstakingly carried out resulted in the production of the four fire situation maps which you see here displayed.

XIX DR. PURCELL: I should like to say how much we have appreciated the help of the Scientific Advisers during the past year. Additionally I know that you will not wish to close without allowing me to say to the Commandant of the Staff College how much we appreciate the kindness and hospitality that we have received during this Conference. We particularly appreciate his magical touch with the weather; the sun always shines when we come here. Thank you very much indeed.

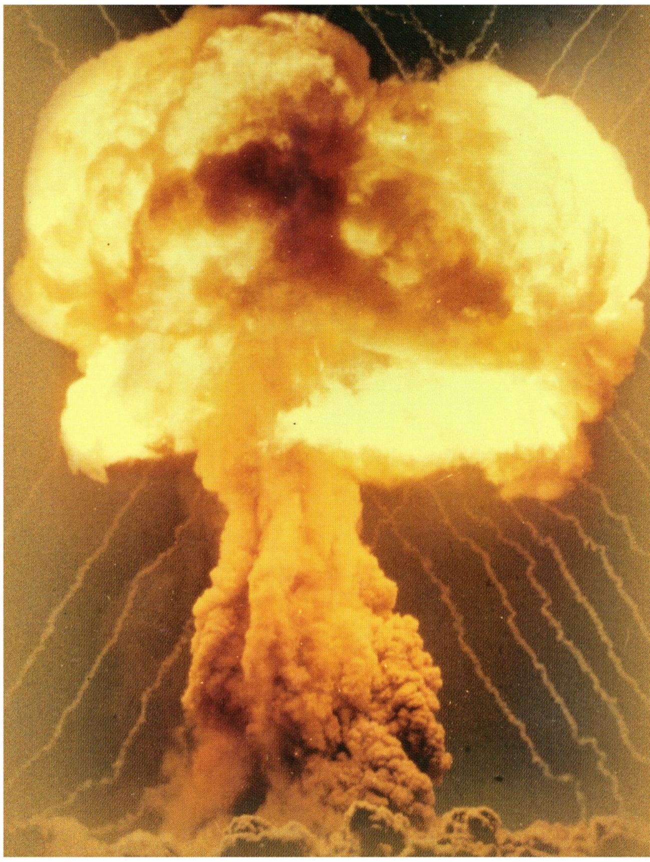
Top of fireball is cooled by water entrainment; bottom is blocked by city skyline (or clouds) duh

BRAVO (15 megatons or 22 megatons) seen not from an aircraft above cloud cover, but from surface level: clouds block hot base of fireball!

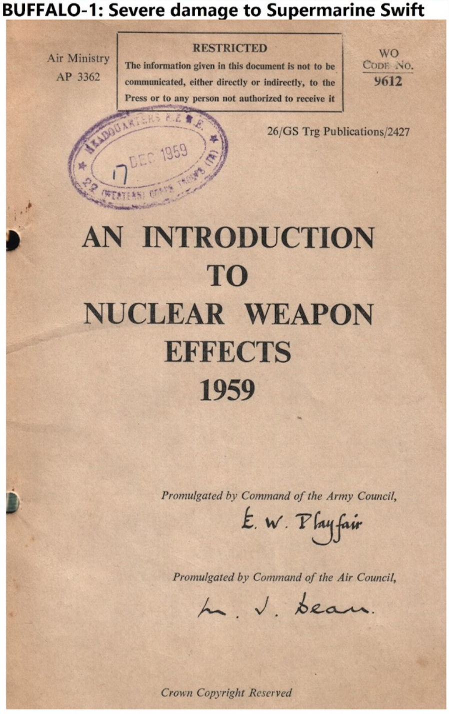
Fireball shielding by clouds (and people), 1.37 Mt Koa, 1958

BUFFALO-1: Severe damage to Supermarine Swift

Operation Antler, Maralinga, 1957.



25 kt composite core (Pu239 within U235) tactical air burst on 9 October 1957, held by balloon at 300m



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26/GS Trg Publications/2427

AN INTRODUCTION
TO
NUCLEAR WEAPON
EFFECTS
1959

Promulgated by Command of the Army Council,
E. W. Playfair

Promulgated by Command of the Air Council,
M. J. Dean

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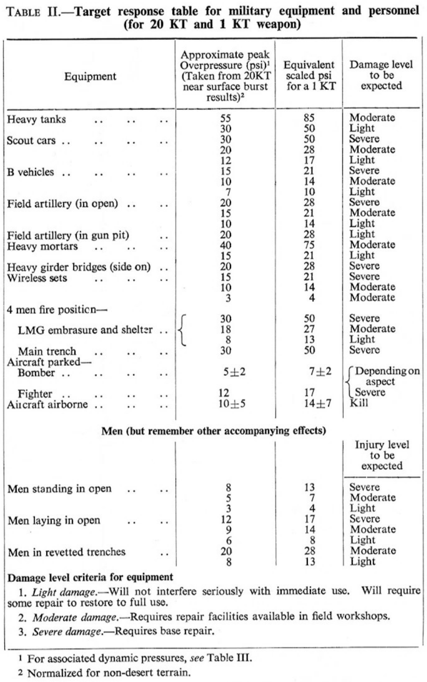

TABLE II.—Target response table for military equipment and personnel (for 20 KT and 1 KT weapon)

Equipment	Approximate peak Overpressure (psi)[1] (Taken from 20KT near surface burst results)[2]	Equivalent scaled psi for a 1 KT	Damage level to be expected
Heavy tanks	55	85	Moderate
	30	50	Light
Scout cars	30	50	Severe
	20	28	Moderate
	12	17	Light
B vehicles	15	21	Severe
	10	14	Moderate
	7	10	Light
Field artillery (in open)	20	28	Severe
	15	21	Moderate
	10	14	Light
Field artillery (in gun pit)	20	28	Light
Heavy mortars	40	75	Moderate
	15	21	Light
Heavy girder bridges (side on)	20	28	Severe
Wireless sets	15	21	Severe
	10	14	Moderate
	3	4	Moderate
4 men fire position—			
LMG embrasure and shelter	30	50	Severe
	18	27	Moderate
	8	13	Light
Main trench	30	50	Severe
Aircraft parked—			
Bomber	5±2	7±2	Depending on aspect
Fighter	12	17	Severe
Aircraft airborne	10±5	14±7	Kill
Men (but remember other accompanying effects)			Injury level to be expected
Men standing in open	8	13	Severe
	5	7	Moderate
	3	4	Light
Men laying in open	12	17	Severe
	9	14	Moderate
	6	8	Light
Men in revetted trenches	20	28	Moderate
	8	13	Light

Damage level criteria for equipment

1. *Light damage.*—Will not interfere seriously with immediate use. Will require some repair to restore to full use.
2. *Moderate damage.*—Requires repair facilities available in field workshops.
3. *Severe damage.*—Requires base repair.

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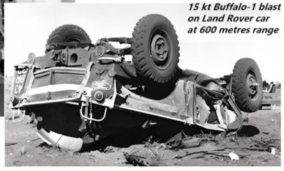
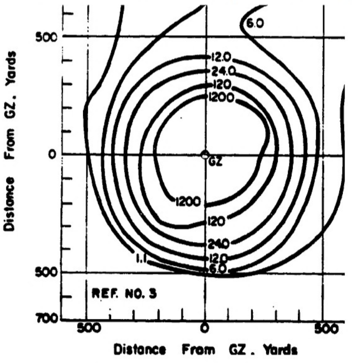
[1] For associated dynamic pressures, *see* Table III.

[2] Normalized for non-desert terrain.

Antler (left) and Buffalo (below) Maralinga nuclear tests



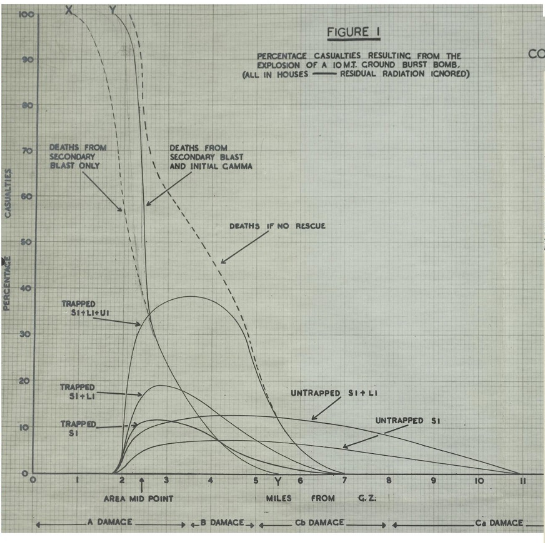
15 kt Buffalo-1 blast on Land Rover car at 600 metres range

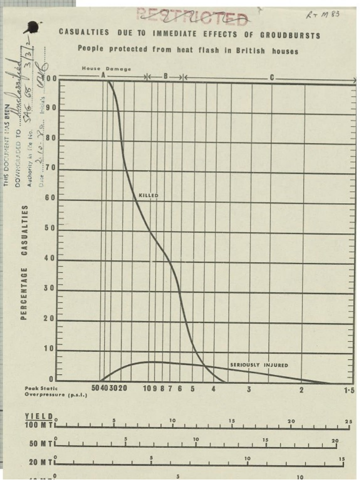


Operation BUFFALO - Round 4.
Crater region dose-rate contours
in r/hr at H+1 hour.

R&M 45

CONFIDENTIAL





UK NATIONAL ARCHIVES: ES 5/2

ANDERSON SHELTER TESTS AGAINST 25 KT NUCLEAR NEAR SURFACE BURST (2.7 METRES DEPTH IN SHIP)

AWRE-T1/54, 27 Aug. 1954

SECRET—GUARD

ATOMIC WEAPONS RESEARCH ESTABLISHMENT
(formerly of Ministry of Supply)

SCIENTIFIC DATA OBTAINED AT OPERATION HURRICANE
(Monte Bello Islands, Australia—October, 1952)

$$p = \frac{130 \times 10^9}{R^3} + \frac{7 \cdot 7 \times 10^6}{R^2} + \frac{13 \cdot 5 \times 10^3}{R} \text{ p.s.i.}$$

Fig. 12.1, Andersons at 1380 ft range from bomb ship shown in the photo, moored 400 yards off shore.

Left: Fig. 12.3, Andersons at 1800 ft after burst. Right: Fig. 12.4, Andersons protected by blast walls at 2760 ft.

12.1. *Blast Damage to Anderson Shelters*

At 1,380 feet, Fig. 12.1, parts of the main structure of the shelters facing towards and sideways to the explosion were blown in but the main structure of the one facing away from the explosion was intact, and would have given full protection. At 1,530 feet, Fig. 12.2, the front sheets of the shelter facing the explosion were blown into the shelter but otherwise the main structures were more or less undamaged, as were those at 1,800 feet, Fig. 12.3.

At 2,760 feet, Fig. 12.4, some of the sandbags covering the shelters were displaced and the blast walls were distorted whilst at 3,390 feet, Fig. 12.5, the effect was quite small. At these distances, the shelters were not in direct view of the explosion owing to intervening sandhills.

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13. THE PENETRATION OF THE GAMMA FLASH

13.1. *Experiments on the Protection from the Gamma Flash afforded by Slit Trenches*

13.1.1. The experiments described in this section show that slit trenches provide a considerable measure of protection from the gamma flash. From the point of view of Service and Civil Defence authorities this is one of the most important results of the trial.

13.1.2. Rectangular slit trenches 6 ft. by 2 ft. in plan and 6 ft. deep were placed at 733, 943 and 1,300 yards from the bomb and circular fox holes 2 ft. in radius and 6 ft. deep were placed at 943 and 1,300 yards.

The doses received from the flash were measured with film badges and quartz-fibre dosimeters in order to determine the variation of protection with distance, with depth and with orientation of the trench and the relative protection afforded by open and covered trenches.

In general, the slit trenches were placed broadside-on to the target vessel but at 1,300 yards one trench was placed end-on. Two trenches, one at 733 and one at 943 yards were covered with the equivalent of 11 inches of sand.

TABLE 13.1

Variation of Gamma Flash Dose on Vertical Axis of Trench

Type of trench	Rectangular broadside-on open			Rectangular end-on open	Circular open		Rectangular broadside-on covered	
Distance (yards) ...	1,300	943	733	1,300	1,300	943	943	733
Surface dose (Roentgens)	300	3,000	14,000	300	300	3,000	3,000	14,000
Depth below ground level (inches)								
6 ...	150	1,000	—	230	214	1,200	(75)	—
12 ...	75	430	—	150	120	545	47·6	—
24 ...	33·3	150	584	60	54·5	188	25	(140)
36 ...	23	70	216	31·6	30	86	13	(56)
48 ...	(20)	43	100	20	17·7	48·5	7·7	(31)
60 ...	—	(37·5)	61	13·6	10·7	(33·3)	5	(23)
72 ...	—	—	(46·7)	(8·6)	7	—	(3·5)	—

Entries in brackets are extrapolations or estimates.

1982 Anderson shelter (Domestic Nuclear Shelters - Technical Guidance)

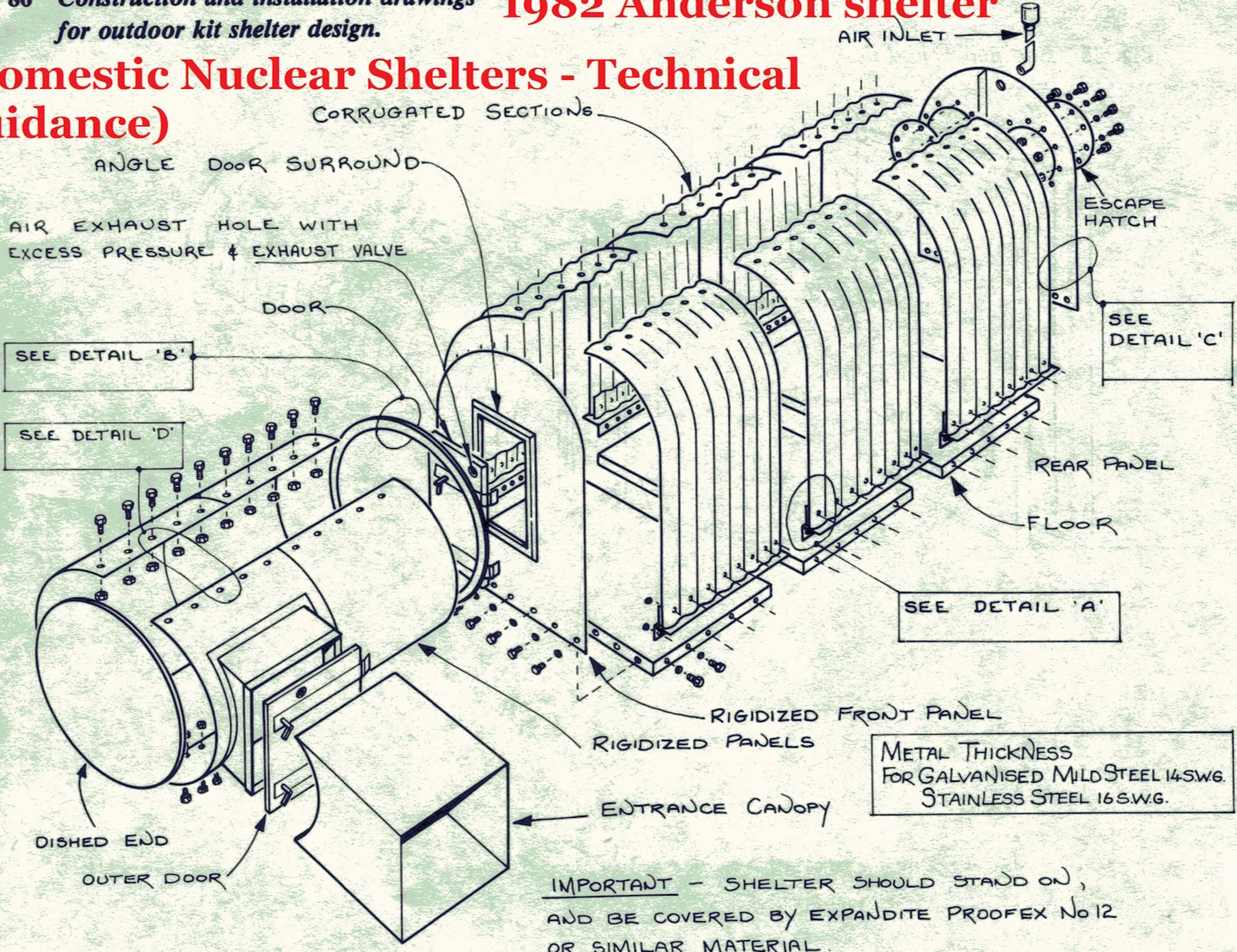
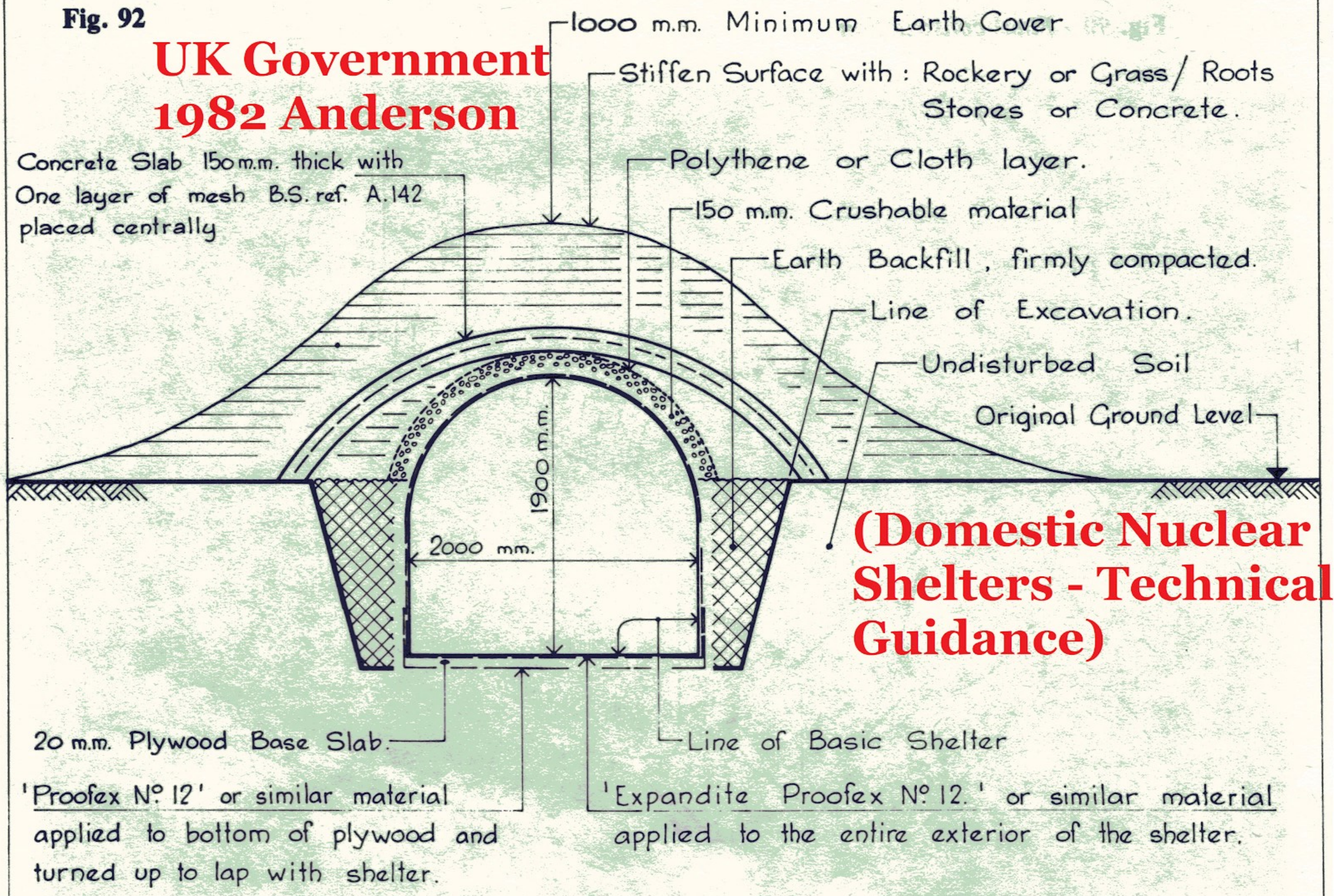


Fig. 86 *Construction and installation drawings for outdoor kit shelter design.*

Fig. 92

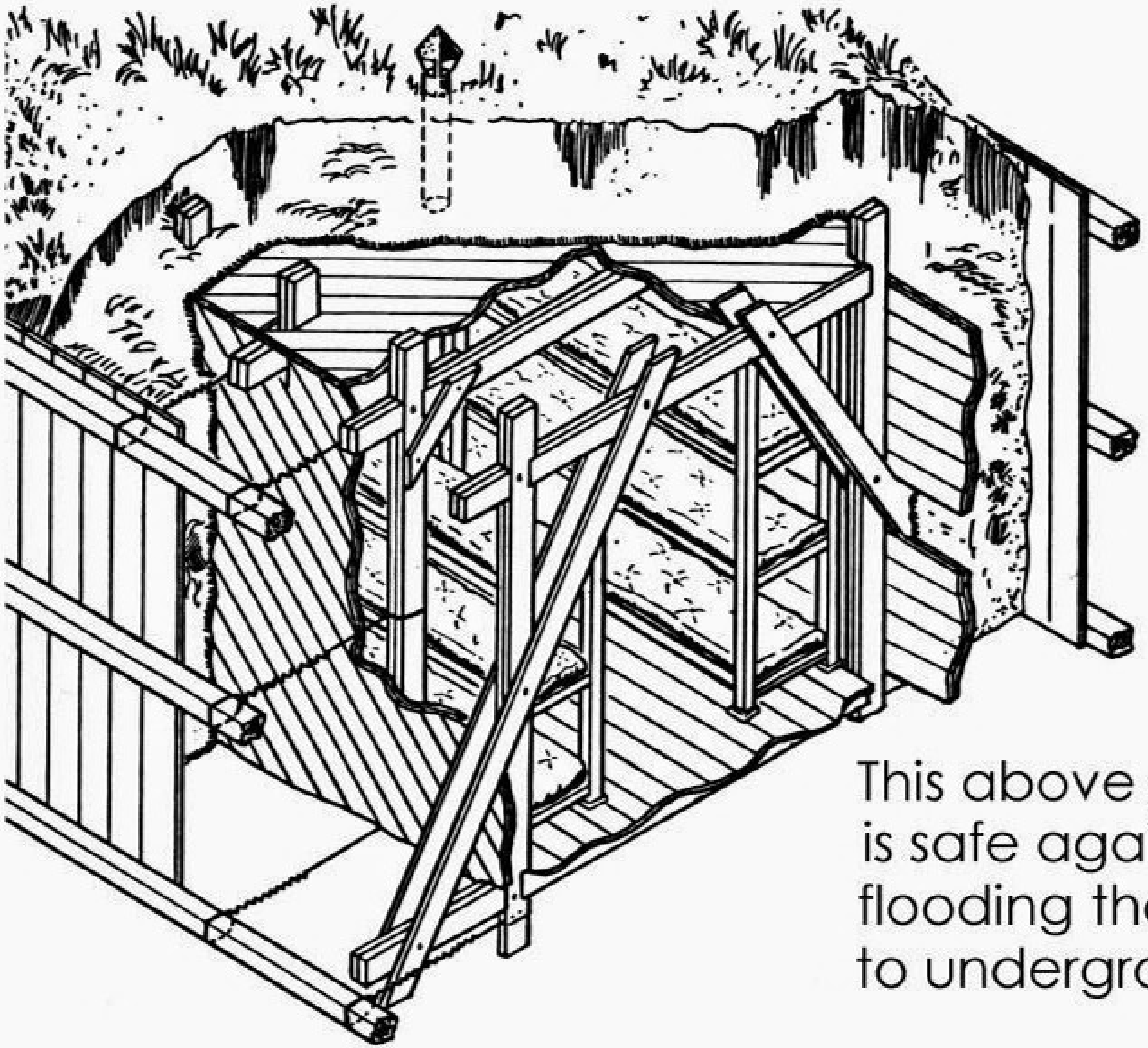
UK Government
1982 Anderson

(Domestic Nuclear Shelters - Technical Guidance)



TYPICAL CROSS SECTION : (FLAT BOTTOM)

PROOF-TESTED OUTDOOR ABOVE GROUND WOOD AND EARTH SHELTER



No casualties
in test at 20 ft
(250 kg TNT)

(Minor damage
to shelter from
the crater debris)

This above ground shelter
is safe against ground water
flooding that occurs in winter
to underground shelter/trench.

UK Home Office Research and Experiments Department Bulletin C26, *Timber shelters for countries where timber is plentiful and steel difficult to obtain,* April 1942. This is a surface (not underground) wooden shelter with 2.5 ft earth fills in the gap between two wooden walls, and on roof.

FROM: "Royal Observer Corps Journal",
Feb. 1985, page 26

FRAGMENTS

Feb. '85:
UK, Home Office "FISSION FRAGMENTS" article, reprinted in 'ROC' Journal V27n2

PROTECTION AGAINST RADIATION

A. L. Mather ex-SA, Northumberland

In 'Protect and Survive' a recommendation is made on page 11 para. 2 'Use tables if they are large enough to provide you all with shelter. Surround them and cover them with heavy furniture filled with sand, earth, books or clothing'. Similar shelters are proposed in paras 1 and 3.

Apart from the fact that under certain circumstances of location and weather sufficient soil may not be available, none of the materials suggested for radiation protection is of use to the shelter-bound occupants. The use of survival supplies as a radiation barrier is to be recommended, if not, indeed considered essential. As previously suggested fuel supplies, which have a half value thickness approaching that of soil, could be used in this way. Food supplies should be stacked in boxes as the inner protective barrier together with immediate water supplies. Water has a half value thickness of 200mm compared with 140mm for earth. One therefore has only to create a water barrier 50% greater in width to equate with a soil barrier. The water barrier can be erected in a very short time merely by filling suitable containers by means of a hosepipe. In this way an adequate shelter can be made in a fraction of the time needed for the filling and transportation of sandbags. Further this would provide a strategic supply of water for fire fighting, drinking, washing and for the later survival period during which water supplies may be limited.

Cheap containers would be needed for such a barrier and dustbins, plastic bottles etc would be expensive and inconvenient to store when not required. There is, however, a suitable container made by Bowater Scott Ltd (and possibly by other companies) which is used for the conveyance of milk. These are double walled plastic bags of five gallon capacity with screw caps. The bags are supplied flat together with fold flat heavy duty cardboard boxes. When the box is erected and the plastic bag within is filled, it takes the shape of the box and forms a fairly rigid 'brick' of water of dimensions 25 cm × 24 cm × 42 cm. These bricks may be stacked to a height of 4 units (on their side) without bursting or collapsing. The bags are very strong and access may be made to them by cutting a sealed plastic tube which is attached to the screw top. Additives would be required to prevent the growth of algae or bacteria.

Not only can one stack these water bricks above and around the shelter but these could also be put on upper and attic floors to improve radiation protection in the fall out room. It would also improve fire protection in the upper floor of the building. The cost of these bags is low (£592 per 1000 including cardboard box). Doubling the thickness of the box to improve stacking properties would increase the cost of the box by 50%. No doubt the price could be improved by simplification of design and by mass production.

One weakness of such a system is the susceptibility of the water bags to rupture by blast damage. Those bags exposed to windows or openings should be protected by a suitable tough barrier such as carpets, heavy timber and/or doors.

There would be load limitations on some types of floor and this aspect would need to be discussed with builders before installation. However as the half thickness for water is larger than that for soil then the equivalent weight of water would be spread over a larger area of the floor.

The progressive reduction of radiation being received by the shelter will allow the progressive use of water from the radiation barrier. The empty water bags may be used to store waste liquids.

This system would perhaps find its primary application to indoor shelters but there is no reason why water may not be used to supplement barriers in other types of shelter. The containers in collapsed form are compact and may be stored in lofts or sheds. In an emergency the barrier may be erected and filled by a hosepipe in a very short period of time without any great effort. This would be of considerable help to elderly or infirm people and, in fact, to most people with only a short time to construct a shelter.